A44

The Kent Incorporated Society for Promoting Experiments in Horticulture

ANNUAL REPORT 1960

EAST MALLING RESEARCH STATION

Near MAIDSTONE

KENT

1st October 1959 to 30th September 1960

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April 1961

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THE KENT INCORPORATED SOCIETY
FOR PROMOTING EXPERIMENTS IN
HORTICULTURE

ANNUAL REPORT

(FORTY-EIGHTH YEAR)

1960

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RESEARCH STATION
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KENT

1st October 1959 to 30th September 1960

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The correct abbreviation of the title of this Report is :—
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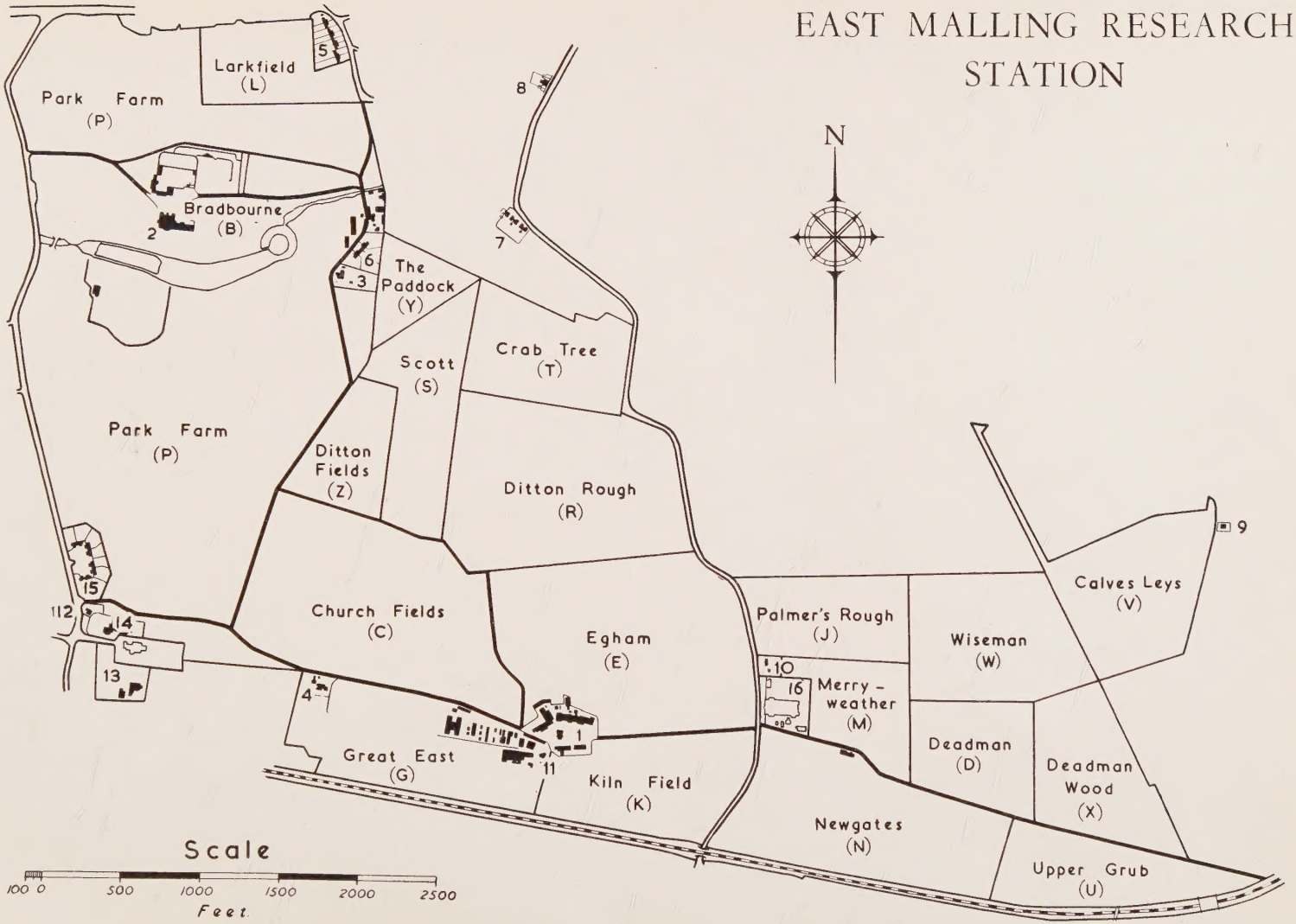

MAP OF RESEARCH STATION LAND SHOWING NAMES OF FIELDS AND REFERENCE LETTERS

The numbers indicate buildings as follows:

1. Laboratories; 2. Bradbourne House; 3. Director's House; 4. Farm Supervisor's House; 5-12. Farm cottages; 13. The Grange; 14. Court Lodge; 15. Staff houses; 16. Ditton Laboratory.

[Frontispiece

ERRATUM

Annual Report 1959, page 118, in line 12, *for* 'peaches 57, vines (mainly sultanas) 35,' *read* 'peaches and apricots 35, vines 132,'.

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GOVERNING MEMBERS OF THE SOCIETY

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T. E. Wimshurst, Chill Mill, Brenchley, Kent.

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Appointed by the West Sussex County Council:

W. Fowle, Costrong Farm, Kirdford, near Billingshurst, Sussex.

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S. D. Garrett, Sc.D., Botany School, University of Cambridge, Downing Street, Cambridge.

Appointed by the Senate of the University of London:

Professor L. J. Audus, M.A., Ph.D., F.L.S., Bedford College, Regent's Park, London, N.W.1.

Appointed by the University of Bristol:

Professor H. G. H. Kearns, O.B.E., B.Sc., Ph.D., The Research Station, Long Ashton, near Bristol.

Appointed by the Governing Body of the Imperial College of Science and Technology:

Professor W. O. James,† M.A., Ph.D., F.R.S., Imperial College of Science and Technology, Department of Botany, Prince Consort Road, South Kensington, London, S.W.7.

Appointed by the Council of the Royal Society:

Professor T. A. Bennet-Clark, Ph.D., F.R.S.A., F.R.S., University of London, King's College, Department of Botany, 68 Half Moon Lane, London, S.E.24.

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D. Skilbeck, C.B.E., M.A., Wye College, Wye, Kent.

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Professor H. W. Miles, D.Sc., Ph.D., Wye College, Wye, Kent.

† Appointed May 1960.

Appointed by the Council of the John Innes Institute:

K. S. Dodds, D.Sc., Ph.D., John Innes Institute, Bayfordbury, Hertford, Herts.

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Lt.-Col. F. N. Richardson, T.D., Messrs. Wigan, Richardson & Co., 15 Southwark Street, London, S.E.1.

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G. E. Tuker, Thorn Cottage, Danbury, Essex.

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C. T. Miller, Wested Farm, Swanley, Kent. (*Deceased September 1960.*)
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R. D. Wickham, Gate House Farm, Brenchley, Kent.

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A. S. Fromow, O.B.E., The Nurseries, Windlesham, Surrey.

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C. R. Favell, Cardinals, Lewes Heath Orchards, Horsmonden, Kent.
P. Wheldon, Newton, Sudbury, Suffolk.

Appointed by East Malling Research Station:

F. R. Tubbs, C.B.E., M.Sc., Ph.D., A.R.C.S., D.I.C., F.L.S.

Appointed by the Staff Council of East Malling Research Station:

Miss E. M. Glenn, B.Sc.

† Appointed May 1960.

MEMBERS OF THE EXECUTIVE COMMITTEE

Governing Members elected at the Annual General Meeting, May 1960:

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Professor T. A. Bennet-Clark, Ph.D., F.R.S.A., F.R.S. (Vice-Chairman).
E. P. Day.
S. R. Dixon, J.P.
K. S. Dodds, D.Sc., Ph.D.
W. Fowle.
A. S. Fromow, O.B.E.
B. S. Furneaux, M.Sc.
Professor W. O. James, M.A., Ph.D., F.R.S.
Professor H. G. H. Kearns, O.B.E., B.Sc., Ph.D.
J. E. Martineau, M.A.
J. W. S. Mount (Chairman).
B. D. Neame.
A. Norman.
Major A. R. Pym.
J. F. Towner.
G. E. Tuker.
E. Vinson, J.P.
P. Wheldon.

The Director:

F. R. Tubbs, C.B.E., M.Sc., Ph.D., A.R.C.S., D.I.C., F.L.S.

The Representative of the Staff Council:

Miss E. M. Glenn, B.Sc.

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Sir Thomas Neame, V.M.H., Macknade, Faversham, Kent.
Sir Edward Salisbury, C.B.E., D.Sc., LL.D., F.L.S., V.M.H., F.R.S., Croindene, Strandway, Felpham, Bognor Regis, Sussex.
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Professor P. F. Wareing, D.Sc., Ph.D., Department of Botany, University College of Wales, Aberystwyth, Wales.
Captain R. Wellington, M.C., Colescus, Gorran Haven, St. Austell, Cornwall.

STAFF

(1st October 1960)

Director : F. R. Tubbs,* C.B.E., M.Sc.(Lond.), Ph.D.(Lond.), A.R.C.S., D.I.C., F.L.S.

Advisers to Director : T. N. Hoblyn,* O.B.E., Dip.Hort.(Wye).
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R. J. Garner, M.Sc.(Reading), N.D.H., Dip.Hort.(Reading).

* Recognized Teacher of the University of London.

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Miss S. CHURCH.
R. J. WALLER.

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W. C. C. HADLOW.
Miss F. LAMB.
Miss M. E. HOPGOOD.
T. J. K. SHOWLER.
P. B. HALDENBY.

† New appointment 1959-60.

Biochemistry: A. E. Flood, M.A.(Cantab.), Ph.D.(Manc.).
A. R. N. Gorrod, M.Sc.(Bristol), Ph.D.(Glasgow), A.R.I.C.

Assistants (Scientific):
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Miss K. N. Dexter.

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B. A. Turfrey.
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J. E. Stickels.
Miss J. Brooking.
Mrs. G. A. Pierce.
Miss J. M. Gooding.
Miss S. J. Cogger.
Miss P. Edwards.
Miss M. K. Davies.
Miss G. Bircham.†
Miss S. A. Luck.

† New appointment 1959-60.
‡ Field records: also attached Entomology and Plant Protective Chemistry.

Entomology: G. H. L. Dicker, Ph.D.(Lond.), A.R.C.S.
A. M. Massee,* O.B.E., D.Sc.(Lond.).
R. S. Pitcher, Ph.D.(Lond.), Dip.Agric.(Wye), Dip.Ento.(Wye).
Miss E. Collyer, Ph.D.(Lond.)
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Miss M. Gratwick, M.Sc.(Lond.), D.I.C.
R. G. Gambrill.
J. B. Briggs, B.Sc.Hort.(Reading), M.Sc.(Lond.).

Assistants (Scientific):

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G. J. Hitchings.
D. W. Jenner.
Miss D. I. Wells.
Miss B. S. Ranft.
H. E. Brickell.†

Plant Protective Chemistry: A. H. M. Kirby, M.Sc.(Lond.), Ph.D.(Lond.), F.R.I.C.
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E. L. Frick, B.Sc.(Wales).
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Miss M. E. Brown.

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T. E. Walter, B.Sc.(Edin.).
B. F. Self, B.Sc.Hort.(Nottingham).

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Assistant (Scientific):

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C. H. W. Slater.

Librarian: S. R. Ball, B.A.(Lond.), F.L.A.

Photographer: E. Yoxall Jones.

Assistant (Scientific):

Miss R. J. Dolling.†

* Recognized Teacher of the University of London.
† New appointment 1959-60.
‡ Also **Fruit Storage Investigations** (in collaboration with Ditton Laboratory).

FARM STAFF

Superintendent of Field Experiments : F. H. Villiers, M.Sc.Agric.Econ., B.Sc.Agric.(Reading), N.D.A.

Assistant Plantations Officer: Miss B. F. Seymour.

Experimental Nurseries : H. R. J. Byford.

Experimental Greenhouses : M. M. MacNeill, M.Sc.(Lond.), C.D H.(Glas.).
A. Tidy.
M. Cole.

Bradbourne Gardens : N. S. Gibbens.†

Workshops : G. G. M. Weller.
F. A. King.
A. C. Whyatt.

Farm Staff with twenty-five years' service :

C. Bates, B.E.M. (45).
J. Denyer (40).
E. Wenham (40).
H. Crittenden (37).
E. Hayes (37) (*Caretaker*).
W. Henson (36) (*Fruit Foreman*).
W. Jenner (34).

ADMINISTRATION

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Director's Personal Secretary : Mrs. R. Cook.

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Mrs. P. R. Osborne (*née* Watson).
J. A. G. King-Fisher.
F. Daly.
Miss C. J. Moorfield.
Miss A. E. M. Griggs.†

Housekeeper : Mrs. I. N. Stewart.†

† New appointment 1959-60.

THE COMMONWEALTH BUREAU OF HORTICULTURE AND PLANTATION CROPS

Accommodated at Bradbourne, East Malling Research Station.

Director : G. K. Argles, Dip.Hort.(Wye), A.I.C.T.A.

Consultant Director : F. R. Tubbs, C.B.E., M.Sc.(Lond.), Ph.D.(Lond.), A.R.C.S., D.I.C., F.L.S.

Assistant Director : G. E. Tidbury, B.Sc.(Lond.), A.R.C.S., A.I.C.T.A.

Assistants : Miss K. H. Carver, B.Sc.(Lond.).
Miss P. J. Rowe-Dutton, B.Sc.Hort.(Lond.).
Mrs. E. Ulyatt, Dip.Hort.(Eisgrub).
Miss E. M. J. Napier, B.Sc.Hort.(Lond.).
J. T. Forrest, B.Sc.For.(Aberdeen).†

Clerical Staff : Miss M. B. Rogers, Miss M. M. Durling, Miss M. Edwards, Mrs. E. M. Hopkins, Miss A. V. Pettitt.

NATIONAL AGRICULTURAL ADVISORY SERVICE

Accommodated at East Malling Research Station

Telephone : West Malling 2418.

REGIONAL FRUIT ADVISORY OFFICER, SOUTH-EASTERN REGION :

F. A. Roach, B.Sc.Hort.(Reading).

Clerical Assistant : Mrs. D. Nye. (*Part-time.*)

† New appointment 1959-60.

GENERAL DEVELOPMENT AND ACTIVITIES

In its reports in previous years, the Committee has usually been able to point to some more or less joyous occasion which might be regarded as the outstanding event of the year. In this Forty-eighth Report on the general activities of the Station the note is more subdued. Sometimes the inexorable passage of time has brought the retirement of this or that member of the research staff; this year we must report the Chairman's decision to make way for a younger man, while two other familiar and well-loved personalities will no longer grace its meetings.

Likewise, at the Agricultural Research Council, a new Secretary has succeeded Sir William Slater, who for a decade has guided its fortunes.

All four of these worthies have had an important part to play in the development of this Station, but so well have they prepared and nurtured the ground that it should not be too difficult for their successors to reap where they have so surely sown and to make the most of each succeeding season for the benefit of science and horticulture.

Thus, while the 1960 sky is cloudy (and the year certainly went out in a torrent of rain), the outlook for the future is ' set fair '.

The Committee would like to wish long life, health, happiness and success to its new Chairman, Mr. J. W. S. Mount, and to the new Secretary of the Research Council, Professor E. G. Cox.

Obituary

We regret to record the death in September of Mr. C. T. Miller, of Swanley. Mr. Miller was nominated by the Kent N.F.U. to succeed his father on the Governing body in 1945, and has been a good friend to the Station in the years that have passed all too quickly since that time.

Governing Members

Indeed, time marches swiftly, and it was with a shock that it was realized that the three-year period of office of the Governing Body had been concluded and that, all too soon, the Committee would once again have to say ' Farewell ' to some of its members.

This year the last member who was also on the original Committee of Management, Professor V. H. Blackman, retires. Four years ago he gave up the office of Vice-Chairman of the Executive Committee, but he has continued to represent the Imperial College as a Governing Member and to serve as a member of the Executive Committee until now. How much the Station owes to Professor Blackman must be evident to those who have followed these Annual Reports, and its indebtedness is to some extent acknowledged in the foundation of the Blackman Research Studentships. Now we can only salute him in his retirement.

The year 1928 was a notable one, for in that year Mr. T. Neame and Mr. E. Hardy both joined the Governing Body for the first time, representing the Kent N.F.U. and the South Eastern Agricultural College, Wye, respectively. In the thirty-two years that have passed, both have become familiar figures at East Malling and have served the Station devotedly.

Mr. Neame was soon elected a member of the Executive Committee, and succeeded the late Spencer Mount as Chairman, first of Finance and later of the Executive Committee—of which, we are glad to report, he remains a co-opted member. During the fifteen years that he has been at the helm, Mr. Neame has endeared himself to the whole staff, and there must be few with whom he has not talked personally. It was very appropriate for him to receive a knighthood from Her Majesty in the Birthday Honours for 1960.

Sir Edward Hardy—as we have known him for many years—has been a well-known figure in the county of Kent, as Chairman, first of the Governors of Wye College and later of the County Council, both of which he has represented here. In the sixteen years since he became a member of the Executive he has given the Committee the benefit of his wise counsel on many occasions, especially on financial matters. Only a few years ago we were able to report that the Society was now the owner of the whole of the Research Station, through the acquisition of Great East field from the County Council. We suspect that it was largely through Sir Edward's influence that this transaction was so easily effected.

Both Sir Thomas Neame and Sir Edward Hardy have now joined the limited but distinguished band of Honorary Fellows of the Association.

Mr. R. E. Hardwick, who replaced the late Mr. Curzon Lewis as the representative for the East Sussex Council in 1953, has also retired, and we are sorry to lose his services.

Two of those who have now become Governors of the Society in succession are already well-known at East Malling. Professor James, who now represents the Imperial College, was first co-opted to the Executive Committee three years ago; while Mr. B. D. Neame, who has succeeded his father as one of the Kent N.F.U. representatives, has been a familiar figure at Members' days and on the cricket field for several years. Mr. A. J. C. Farlow is the new representative of the Kent County Council and Mr. W. W. Youdale of the East Sussex County Council; Miss E. M. Glenn was re-elected to represent the Staff Council for a second year.

Eighteen Governing Members came on 22nd June, the day specially arranged to show them details of research in progress. In the morning they were taken on a conducted tour of the newly-acquired Trust Land. In the afternoon the research workers concerned described studies in the control of *Gloeosporium* rots, skin finish, and biochemical factors in the storage qualities of Cox's Orange Pippin.

The Development Fund

Sir Thomas Neame has been appointed a Trustee of the Development Fund. Members will need no reminding of how much this Fund, and the Trustees who administer it, mean to the Station as a whole.

Committees

Regular quarterly meetings of the Finance Sub-Committee and the Executive Committee were held throughout the year. Immediately following the Annual General Meeting, Mr. J. W. S. Mount was elected to succeed Sir Thomas Neame as Chairman, while Mr. S. R. Dixon was appointed in his place as Chairman of the Finance Sub-Committee. Professor Bennet-Clark was re-elected Vice-Chairman of the Executive, and new Members elected to the Committee were Major A. R. Pym and Mr. B. D. Neame. At the same time the members of the various sub-committees—Finance, Building, Plant Prices, Farming and Studentships—were also appointed. The appointment of Professor James to the Governing body created a vacancy amongst the six distinguished co-opted members of the Executive ; Sir Thomas Neame was promptly elected to fill his place.

Last year saw the appointment of a special sub-committee to review subscription rates for members of the Association ; the results of their work, which has been considerable, are detailed below.

The Trust Land

As is detailed in the Farm Report (p. 1), part of the 140 acres acquired by the Development Fund was taken over in the autumn of 1959 and is now being farmed, although none has yet been used for experimental purposes. However, a start has been made to clean the land and prepare for its eventual use. During the year the newly-acquired fields have been named (see frontispiece of this Report); for the most part the historic names of these fields are used, as has been the practice in the past. One field near to Ditton Court, for which no name could be found, will be known as ' Scott ', after Tom Scott who was the owner of Ditton Court Farm at the time of the purchase of Great East field in 1912 ; it was then part of that farm.

In the meantime, the Committee has been concerned with many matters connected with the take-over of new land ; these include farm roads and fencing, footpaths and rights-of-way, the supply of water and electricity, the efficient control of the more distant parts of the farm (e.g. the north-east corner of Calves Leys), and the safeguarding of farm and research workers and their experiments from debris and dust from Ditton quarry.

It is expected that the first experimental plantings on Palmer's Rough and part of Calves Leys will be made in the autumn of 1961. To ' compensate ', it is planned to ' rest ' parts of Churchfields, Kiln Field and Newgates for a longer period than would otherwise have been possible without drastic curtailment of field experiments.

Association Subscriptions

The Annual General Meeting in May accepted the recommendation of the Executive Committee for the revision of the subscription rates for Members of the East Malling Research Station Association. The changes will take effect in January 1961. This bald statement covers a great deal of work carried out by the sub-committee and by the office staff. Many Members had not been heard of for very many years ; some became ' Life ' Members in the early days and others have simply paid their subscrip-

tion by banker's order annually. It is gratifying that several Life Members have made donations to the Association's funds, while others have agreed to make annual subscriptions in future.

The main change brought about by the revision is the relation of the subscriptions of those actively engaged in the commercial growing of fruit or hops, or in raising fruit trees, to acreage. Thus, while the grower with 1-9 acres of fruit will subscribe three guineas, the grower with 100 acres or more will subscribe ten guineas. The appropriate subscription for amateurs and all others with an acre or less of commercial fruit is unchanged. Fellows' subscriptions will be raised by 50% to fifteen guineas, which rate also applies to all outside the British Commonwealth except for *bona fide* research workers. Advisory officers and employees of Members are still eligible to join as Associates at one guinea subscription.

It remains to be seen in 1961 what effect these changes will entail, both in the number of Members and the total subscribed. It is inevitable that there will be some resignations, but it is encouraging to report that, from the time the revision was first talked of up to the end of September, fifty-one *new* Fellows, Members and Associates will be registered in January 1961.

It should be noted that the Agricultural Research Council has now agreed to stabilize the annual subscription from the Association towards research expenditure at £1,400, instead of relating it to the total subscribed each year, as formerly. Thus, any income over and above the pre-revision total will go directly towards those objects that cannot be supported by the State, and which the Committee has so much at heart.

The Working Week

Although no change was made before the end of the year, active discussions have been in progress concerning the working week for the research and administrative staff, taking into consideration the expressed wishes of the staff and difficulties in transport—particularly during the summer months—on Saturday mornings. It should be emphasized that no changes were proposed that would alter the total number of hours of work each week, or holiday periods. As a result of discussions, in future the staff for the most part will normally work longer hours on five days in the week, but will not work on Saturday mornings. Arrangements are being made for the reception of unheralded visitors and to deal with urgent administrative matters ; the farm staff will continue to work on Saturday mornings, as before. Of course, some research workers will find it necessary to come to their laboratories or visit their field experiments every day of the week, including Sundays (especially at certain times in the year), as they always have done. It is expected, therefore, that when the new arrangements come into force in October the Station's work will not be materially affected.

General

The Committee would like to express its indebtedness to Mr. J. F. Towner, who has for many years kept a keen and wary eye on the maintenance of, and repairs to, existing buildings, and has always been ready with advice and assistance when new buildings have been acquired.

The five farm cottages acquired with the Trust Land have been put in repair and two terrace cottages at Ditton have been bought. Work has been progressing steadily at Bradbourne, and it can confidently be predicted that—early in the New Year—the Bureau will be in occupation of a number of rooms in the neighbourhood of the Judge's passage that have been reconditioned for its use. Substantial repairs have been carried out at Court Lodge, and an underground ' laboratory ' (a development of the root trenches, which some Members will remember) for the observation of root growth has been constructed in Egham Field, near the laboratories. The accommodation for the innumerable variety of mechanically propelled and push bicycles has been extended.

The small rise in the rentals at the Grange, reported last year, proving to be insufficient, a further increase had to be made in the spring. Even now, it seems that the charges at the Station's hostel compare favourably with those of similar establishments elsewhere.

Although the final accounts for the year's working in the Canteen will not be available until the end of the calendar year, the measures adopted in recent years have succeeded in placing the Canteen on an even keel financially, and we are glad to hear that not only have its depleted reserves been made up but deficiencies in equipment—brought about by straitened resources in recent years—have been made good.

The meetings of the Executive Committee have been enlivened by reports and discussions on a variety of subjects of particular interest to fruitgrowers. These have included silver leaf in plums, storage scald, classification and identification of hardy fruits, Botrytis in strawberries, the soil-reactions survey of the Station (see p. 77), the work of the N.A.A.S. Experimental Horticulture Stations, and research developments in general.

The Cost of Research

The researches of this Station are done in the laboratories and on the experimental farm. Although there has been a slowing down of new research appointments recently, there were very many of them in the years following the war, so much so that in the Staff List (p. vii) will be found the names of nearly 80 qualified research workers, with about 60 assistants. It is obvious that these cannot work alone, so that—apart from the farm staff—there must be an adequate administrative staff to serve their needs. All these must be paid salaries consistent with those in similar occupations and with the cost of living. Since the staff forms the backbone of the Station, and without them no research could be accomplished, it is hardly surprising that three-quarters of the large grant from the Agricultural Research Council is devoted to salaries.

A team of this size cannot work in a vacuum ; buildings and laboratories have to be maintained and the cost of the experimental farm is much greater than the value of the produce that can be sold. As Members are well aware, worthwhile experiments very often yield valuable results, but though these may mean better financial returns to fruitgrowers, they do not increase the Station's income. Nevertheless, the grant to meet these liabilities—though much less than the cost of the salaries—has to be strictly controlled, and is very carefully budgeted for. Taxpayers will readily understand that the resources of the State are by no means unlimited, so that the more the demands on it can be reduced by meeting the liabilities from other sources, the better.

Apart from a small but significant grant from the Association, the only substantial source of income available to the Committee is the saleable produce of the farm. If fruitgrowers need any reminding of the year that has past, they have only to read the Farm Report (p. 1) to realize that the experiences here were the same as their own. Sales of produce were down by about £8,000, and this has meant that a corresponding amount has had to be asked for from the Agricultural Research Council over and above the original estimate.

The East Malling Research Station Association

The above notes on the bare cost of research emphasize the part that the Association can and does play in the welfare of the Station. As has been said, a small direct grant of money is made annually, but there are many expenses in connexion with a community of this size for which the State may not provide, and these have been met by the Association. Thus, looking to the future, by means of its studentships, young men are enabled to train here to fill the ranks of research workers who retire; pensions are provided for retiring farm staff; scientists are helped to enlarge their experience by visiting fruit-growing districts in other countries, viz. Dr. Rogers' journey to the Antipodes in 1959 and Mr. Preston's to Italy in 1960 ; the evening class fees of enthusiastic youngsters are met ; while provision is made so that the capital needs for staff recreation are covered. Above all, without the Association's active participation and support, the Trustees of the Development Fund could never have acquired, in 1959, the 140 acres of land that will ensure the continuation of efficient field experiments for the next quarter century.

The attempts that are being made to restore the Association's income to its pre-war value, to meet the present-day cost of these items, have already been outlined; it will remain for next year to show how far they will be successful. In the meantime, many Members have not waited to show their appreciation, with the result that by increased subscriptions and by donations the income rose by £1,180 in the past year, reaching a total of £5,395.

The Accounts and Balance Sheet for the year are given opposite. It will be noted that nearly one-third of the income was expended on rent of the land and farm cottages now owned by the Development Fund. The capital cost of resurfacing the tennis courts (built by the Association twelve years ago) has been met, thus enabling the Club to carry on, covering its own running costs as in the past.

Members' Days

After the very dry summer of 1959, the review of research on soil moisture requirements, which preceded the Amos Memorial Lecture on 19th November, proved very popular. Trials with apples, raspberries and black currants were demonstrated, and attention was drawn to the conditions under which irrigation was likely to prove worth while.

The keeping quality of variously-grown Cox's Orange Pippin apples was discussed on 15th March. The progress of research on the control of *Gloeosporium* rots was described in the morning and the wastage due to other storage troubles (especially shrivelling and bitter pit) in the afternoon.

After the Annual General Meeting on 9th May, Members inspected some of the plantations or discussed informally particular subjects of research in which they were interested.

On 29th June a half day was devoted to recent developments in the work on virus diseases of strawberries, especially green petal and Arabis mosaic, and on pests of soft fruit, including leafhoppers, eelworms, raspberry beetle and strawberry seed beetle.

The East Malling Research Station Association
Income and Expenditure Account
1st October 1959 to 30th September 1960

Expenditure	£	s.	d.	Income	£	s.	d.
Contribution to Research Costs ..	1,400	0	0	Subscriptions and Donations	5,395	0	9
Rent of Land and Cottages	1,627	3	8	Miscellaneous Receipts	2	17	2
Farm Pensioners	100	0	0	Interest on Loans, etc.	30	2	5
Orchard Experience Overseas	100	0	0	Refund of Income Tax	31	4	4
Evening Class Fees	30	11	0				
Staff Amenities	130	0	0				
Tennis Courts and Cricket Pitch ..	466	9	8				
General Expenses	1,004	7	6				
Surplus	600	12	10				
	£5,459	4	8		£5,459	4	8

The East Malling Research Station Association
Balance Sheet
at 30th September 1960

	£	s.	d.		£	s.	d.
Accumulated Members' Fund :				Freehold property at cost :			
Balance at 30th September, 1959 ..	10,704	8	5	Fircroft and Grange	8,792	13	7
Add surplus for the year	600	12	10	Studentship Endowment :			
	11,305	1	3	Investments at market value	13,549	8	5
Studentship Endowment	16,173	17	2	Cash at Bank	2,624	8	9
Farm Pensioners' Fund	574	5	9		16,173	17	2
Sundry Creditors	790	11	0	Sundry Debtors and Interest ..	273	2	2
				Deficit on Rentals and Farming ..	600	18	1
				Cash at Bank	3,003	4	2
	£28,843	15	2		£28,843	15	2

Amos Memorial Lecture

The fauna of the orchard formed the subject of the twelfth Amos Memorial Lecture. It was delivered on 19th November at the Research Station by Professor V. B. Wigglesworth, C.B.E., M.D., F.R.S., Quick Professor of Biology, University of Cambridge ; the full text was published in the 1959 Annual Report.

Staff

During the past year, as recorded elsewhere, many thousands of miles have been covered by members of staff visiting research institutes and places where fruit is grown abroad. It is all the more gratifying that all but one have eventually come home to roost and, in consequence, there are few changes to report here.

However, inevitably periodic intimations from the Chairman of Staff Council remind the staff of pending retirements. Thus, after seventeen years' service in the Bureau, Dr. V. H. Goldschmidt, who has been a personal friend to so many, retired in September. For eight years Miss A. M. C. Booth presided over the staff canteen, during which time she must have supervised the serving of over a hundred-thousand lunches, many of which she prepared herself ; during the same time she has seen to the cleanliness of the buildings, and has maintained them as a model to other research institutes. We wish them both every happiness in retirement.

In the Pomology Section Dr. Barbara Mosse was seconded in April to the Soil Microbiology Department at Rothamsted ; Miss P. B. Topham, who has been assisting Mr. Tydeman, has been seconded, first to Kew and now to the National Fruit Trials at Brogdale. M. V. Labern left to join the Nature Conservancy staff in November 1959 and was succeeded in the following January by R. Smeeton.

In the Statistics Section there have been several changes: at the end of August, G. H. Freeman left for West Africa, to take up a post at the W.A.C.R.I. sub-station at Ibadan. J. A. Thompson has become a warden-naturalist under the Nature Conservancy in Suffolk and has been replaced by Miss C. M. Harris, who came here from Hull University in August.

While there have been no staff changes in the Physiology Section, it is with some satisfaction that a successful six months exchange of posts during the winter and spring 1959-60 between Miss J. G. Smith and Miss Lotti Hüber of the Wädenswil Research Station, Switzerland is reported.

In October 1960, soon after the end of the year covered by this report, A. R. N. Gorrod resigned his post in the Biochemistry Section.

In April, J. M. Thresh joined the Pathology Section, after six years at the W.A.C.R.I. sub-station at Ibadan. It seems hardly credible that it is so long since he first came to East Malling from the Imperial College of Science as a temporary recorder.

Dr. M. P. Denne, who had been assisting Dr. Montgomery with the fruit storage investigations, emigrated to New Zealand in June, where she will be carrying on similar work at Auckland.

There have been fewer changes than usual among the Assistants (Scientific); two of those who have left are to pursue their studies for an academic degree -R. A. Layberry (Pomology) at the Medway Technical College and J. J. M. Flegg (Entomology) at the Imperial College of Science, London. M. E. Burley, who assisted temporarily in the pH survey carried out by the Fruit Nutrition Section, is now training to become a school teacher at Leicester. Of others who have left during the year Miss J. M. Burren, who was formerly in the Plant Analysis Section and took an active part in the social life of the Station, should be mentioned; she took up an appointment with British Drug Houses at Poole in January.

Statistics lost Miss B. J. Heaton in June. Mrs. A. Bayley (*née* Richardson) resigned from Fruit Nutrition following her marriage in July, as did Miss P. E. Hicks from Scientific Liaison in December 1959. Mrs. B. M. Eaton (*née* Smith), assistant to the Photographer, left in October 1959. Miss J. D. Beckley left Plant Pathology in March, after three years' service.

The names of those who have succeeded them are all recorded in the Staff List, but special mention should be made of Miss Hilda Morgan, who is by no means a newcomer, having joined the Station in October 1946 in the W.L.A. and who is now an Assistant (Scientific) in the Pomology Section.

The Committee is again fortunate in having very little to say about the Farm Staff. The news that Miss K. Greenstreet was to be married was received with delight by many members of staff, for she has served the Station devotedly since she first came here nine years ago. She has now been succeeded in the Bradbourne gardens by N. S. Gibbens, a former Plantation Assistant.

In many ways it has been a difficult year for the office staff, and Mr. Oxley is to be congratulated on having coped with rather numerous changes with so little effect on the day-to-day running of the Station. It is hoped that the introduction of the five-day week after the end of September 1960, may ease staffing problems (see p. xv). W. J. Clarke, Assistant to the Secretary, resigned in August; in future his work will be divided between Miss M. B. Knighton-Hammond and L. G. Martin of the Accounts staff.

We wish all those who have left during the year every happiness and success and, at the same time, welcome their successors.

It is some years since the various internal committees, whose work so helps the Director in the smooth running of the Station—Library, Workshops, Greenhouses, Estate, Photographic Studio, Canteen—have been noticed in these reports. Perhaps their work is not quite so heavy as it was before the appointment of such officers as the Greenhouse Superintendent, the Librarian and the Housekeeper. None the less, day by day problems come up for solution and their continuing work is of the greatest assistance.

Organized Visits

Three staff visits were again arranged in 1960. Profiting by last year's experience of allowing those who went to make their own arrangements for transport and overnight accommodation, a most profitable day, on 7th July, was spent at the National Vegetable Research Station, Wellesbourne, Warwick. Here, after a warm welcome by the Director, Dr. Philp, good use was made of the opportunity for meetings and discussion with the staff of the different departments.

On 30th August there was an expedition to Essex, first to Fontenay Orchards, the farm of Mr. J. D. Edwards, Chairman of the A.C.E. growers, and after lunch to Twinstead Hall, where the party was welcomed and shown around by Mr. Hugh Flower. For both these visits much is owed to an old friend, Mr. Roger Edwards, who did so much to make them a success. Those of the staff who remembered the many trips made to Essex ten years ago in the days of the A.R.C.-Pettar-A.C.E. Red Spider investigation, found much of interest in the developments in the orchards since that time.

Earlier in the year, on 19th July, a party went to Little Barton to see the farms of our Chairman, Mr. J. W. S. Mount. In 1912, his father, the late Mr. Spencer Mount, wrote a paper after his return from North America, which may be regarded as a landmark in the evolution of commercial fruit-growing practice in England. Ever since that time those at East Malling have taken a close interest in the development of these fruit farms, and this year was obviously the one for the staff of today to visit them.

In the eight years since the scheme was started, parties of the research staff have visited seven research institutes, two experimental horticulture stations, the National Fruit Trials at Brogdale and the Essex Institute of Agriculture, Writtle, and well over thirty fruit farms in the south-east. Everywhere they have had the warmest possible welcome and the Committee can only thank all those who have received them and aver once again how much these expeditions are valued. Long may they continue.

Social and Athletic Activities

The social events of the year have been in the hands of Mr. D. A. Holland, who was elected Social Secretary.

At the date of writing the earlier part of the ' summer ' seems very remote and the memory is of an almost continuously wet season ; but with the exception of the Garden Club Show social events were little affected. Even the children's party had a fine afternoon.

Last year Members were exhorted to ' look to their laurels ' ; evidently they have been doing so, for they defeated both the Cricket and Tennis Clubs. The Hockey Club has the advantage of a return match, but when it is realized that each side won their match when away from home, the small suspicion that the minds of those playing at home may have been unduly taken up with the after-entertainment of their guests, to the detriment of their hockey, is inescapable. Apart from these important matches, all these Clubs had good seasons. Great things will be expected from the Tennis Club in 1961, on its newly-surfaced courts.

Inter-sectional staff discussions are becoming a commonplace, but inter-sectional table tennis tournaments, involving nine Sections and 43 members of staff, are an innovation. Congratulations to the Physiology Section for winning.

Members of the Ladies' Netball Club seem to be rather prone to marriage which, while desirable in itself, seems detrimental to the Club's activities ; it is hoped that enough ladies will stay throughout 1960/61 to ensure a more eventful season next year. Members of the Squash Club, however, still make good use of the facilities offered them in Maidstone. With a reconditioned boat house, many members of the Boat Club must be expected on the lake again next year.

Finally, the farm staff have entertained the research staff to a skittles match. As nobody seems to have any idea who won, it is suspected that on that occasion the beer was as important as the skittles !

Play Reading, Films, Music—all continue to be catered for by well-supported Clubs. Due to the efforts of the last, there is now a new piano at Bradbourne.

In California, it was learnt that the inhabitants are becoming so car minded that they are rapidly losing the use of their legs ; two motor rallies here were well-supported and may be a portent of things to come but, from the reports of the athletic clubs, there seems no need to worry yet.

Of course, again there was a Christmas Party, and the main feature was another in the now lengthy list of Barbara Seymour's pantomimes. In paying tribute to her, those who write these entertainments and generally perform in them too should not be forgotten. Probably they enjoy it ; the audience certainly do.

For lack of space, the general social life of the Station, which revolves around such events as the Christmas party, the children's party, the cricket match against the Members, and, last but by no means least, the harvest supper can only be mentioned in passing. But, while all these are eagerly looked forward to and well attended, it is hoped that one of these days there will be an occasion when the whole staff—with their wives and families -can meet together at the same time. In the meantime, however, thanks are due to all those who make these events possible.

Postgraduate Students

Members who have contributed to the scheme, the purpose of which is to train the research workers of the future, will be pleased to know that there are now three Blackman research students. The awards to two of them, M. G. Morris (Entomology) and D. S. Skene (Pomology), have already been reported—both are now registered for higher degrees with London University. The third, to M. D. Coley-Smith from Birmingham University, was awarded in September in the Plant Pathology Section.

After a month here, he is taking a year's course at Bristol University before commencing a research course in bio-chemical aspects of host-pathogen relations in fruit-tree diseases.

The first Boots' Studentship was awarded in October 1960 to M. G. C. Mullins, who will study some of the factors affecting fruit bud formation, in the Pomology Section.

Four members of staff and one whole-time postgraduate student have been awarded higher degrees by the University of London, Miss A. V. Delap and Miss E. M. Ford (Fruit Nutrition), F. W. M. Llewelyn (Physiology) and Asharfi Jha (Pathology) of Bihar, Patnu, India, have all received Ph.D. degrees ; Miss M. Bennett (Pathology) has been awarded the degree of M.Sc.

There are now seven registrations for higher degrees ; four members of staff and three post-graduate students, one of whom came to England in June 1959 from the Tea Research Institute of Ceylon.

Only three students were in residence for shorter periods during the year—all from abroad. M. Shafrir, from Israel, completed nine months' Pomology in March, while Ting Wen Poh from Malaya and T. K. Kandaswamy from India have both been working in the Pathology Section.

If the number of short-term students working here this year seems small, we must largely blame the lack of room ; nearly all laboratory and office accommodation is fully occupied by the permanent staff so, unless a student wishes to work almost entirely in the field, there is very little room to accommodate him.

Temporary Recorders

An attempt was made this year to extend the range of notification of the scheme to science departments of Universities and Colleges, with the encouraging response of a much larger number of applications. Seventeen appointments, each for four weeks, were made from eleven institutes, and it seems evident that the practical insight into field experimentation afforded was greatly appreciated by those fortunate enough to be selected. From the Station's point of view, the average field intelligence and efficiency was of a high order.

It is with some pleasure that we learnt of the first students from Northern Ireland who have come here under the scheme.

Plantation Assistants

All but one of the present team of eleven have come from Farm Institutes, the exception being O. Rokholt, who is an exchange student from Norway and here for a year only. So, with the added knowledge and experience, an exceptionally good report may be anticipated next year.

For the first time the team is exclusively male, though whether that is a good thing or not remains to be seen.

Peter Danks was this year's winner of the Worshipful Company of Fruiterers' prize. While he was here he did well both at work and play ; he has now started a two-year student course at the R.H.S. Gardens, Wisley.

While the Plantation Assistants mainly earn their keep on the experimental farm, by way of some extra return a course of lectures is organized for them throughout the winter months. Many of these lectures are given by members of the research staff, but this year they have been assisted materially by no less than five experts from outside the Station, while Dr. Massee took the Chair at a Brains Trust in which the panel was composed of three former Plantation Assistants. The Committee do most sincerely thank all those who have taken this trouble and can assure them that their efforts are warmly appreciated, not only by the assistants themselves but by those members of staff who go to hear them.

Staff Discussions

Two of the ' general ' discussions, held at Bradbourne and attended by the whole research staff, dealt with particular aspects of research—mycorrhiza and the development of the fruit bud. On the other two occasions the discussion was more general, relating rather to matters of research method. Thus, on the first occasion an attempt was made to define a ' healthy ' experimental tree, while on the second the intricacies of fundamental and applied research were probed.

Older Members may recall the ' spider's web ' diagram, which showed the linkage between the work of the various research Sections. Today it is even less possible to delineate exactly the realm of any one Section ; thus the plant pathologist works hand-in-glove with the biochemist and the division between pomology and physiology is very nebulous. It was therefore stimulating for two nearly-related Sections—Physiology and Fruit Nutrition—to get together in the more intimate atmosphere of the Discussion Room to compare notes on problems of mutual interest. Likewise, there have been

many who have had an interest in the apple manurial trial, from one point of view or another, during the thirty years since the trees were planted, so that there was a large attendance—not only from Sections now directly concerned—to hear of its history and debate its future. Other subjects discussed on various occasions and of interest to more than one were the problem of mite resistance and the effects of nematodes on fruit plants.

East Malling Abroad

Once again we have to thank the Agricultural Research Council for making it possible for representatives of the staff to appear in various parts of the world, ranging from New Zealand to California, either by making direct financial provision or by endorsing the action of the Committee in granting leave of absence so that opportunities financed in other ways could be accepted.

The Director was at the Tea Research Institute in July and August, and doubtless revisited many old haunts in Ceylon. T. N. Hoblyn was away for three months in the spring and early summer, during which time he visited research institutes in North America, ranging from California to Nova Scotia—managing to cross the path of J. E. Crosse, who was in the Western States and Canada with a Rockefeller Travel Fellowship, to say nothing of that of the Chairman of this Executive Committee, who was in Eastern Canada.

J. M. Goode was in East Africa for three months in the beginning of the year, and Miss E. Collyer's scholarship to the Cawthron Institute, New Zealand, has been renewed to enable her to stay there a second year.

In Europe, G. H. L. Dicker, accompanied by Miss M. Gratwick, attended the Entomology Congress in Vienna and visited stations in western Europe. R. L. Knight was in Sweden, Germany and Holland ; A. P. Preston (financed by the Association) studied the fruit-growing districts of Northern Italy ; A. F. Posnette and R. Cropley were both at the Virus Diseases Symposium at Lyngby, Denmark, at the end of July—the latter meeting A. P. Preston on his way home from Italy at Gembloux, Belgium. Earlier in the year A. H. M. Kirby was also at Gembloux ; in March, M. M. MacNeill was also in the Low Countries, studying recent developments in glasshouse design.

Members will greatly appreciate the value of these opportunities to gain experience and exchange ideas ; at the same time the Committee would like to express its thanks to those who have stayed at home and carried on without detriment to the Station's researches during the absence of their colleagues.

Collaboration

Seven years ago the first trees were planted on five farms to demonstrate to fruitgrowers the merits or demerits of five newly-issued woolly aphid-resistant rootstocks, as compared with those in common usage giving similar-sized trees. In subsequent years further units were planted, and there are now more than thirty scattered over the country wherever fruit is grown, from Devon to Norfolk. This has involved collaboration with N.A.A.S. specialist fruit officers and the growers who have found room for the trees on their farms.

While none of these is strictly an experiment, being primarily designed so that fruitgrowers should be able to watch the trees year by year in their own localities, taken in the aggregate, they must yield quite a lot of information about these new rootstocks. This year a team from East Malling has visited all these plots for the first time and, while no final judgment can be expected based on trees that are as yet quite young, taken in conjunction with the results of older properly designed experiments, their report should be of very great interest.

Of all research institutes, the closeness of our liaison with Long Ashton means most to us. There was a time when the research staff as a whole used to visit Bristol, and *vice versa*. Those days have gone, and it is now only possible to exchange visits one Section at a time. The year has marked the first of these regular interchanges, with a warmly-welcomed visit here of the Long Ashton pomologists. It is hoped that such opportunities for mutual discussion between the research staffs of the two institutes will in future occur at frequent intervals.

A new enterprise worth mention is the assistance of the National Institute of Agricultural Engineering in an attempt that is being made to save land by eliminating guard trees in experimental design and substituting for the trees plastic sheets sunk in the ground. The actual insertion of these barriers in the soil is a considerable problem, in the solution of which the assistance of the engineers at Silsoe is much appreciated.

Arrangements have been made for Messrs. Sprent and Holland to deliver a course of lectures on Statistics at Wye College in the coming session.

As usual, there is a long list of collaborative research projects and trials on fruit farms. A work

study in relation to apple picking on variously treated trees is a new departure ; likewise, programming for the electronic computor has probably not been mentioned in these notes before, nor has a machine for reducing whole trees to ' chips ', to facilitate sampling, not for human consumption. Some of the other subjects in which the staff are not working alone are : water sprinkling for frost control ; height of budding in connexion with collar rot ; the isolation and identification of a natural growth inhibitor extracted here from Myrobalan B plum rootstocks ; analysis of soil samples ; a nematode survey of sites where strawberry foundation stocks were to be propagated ; soil-borne viruses ; the identification of fire blight ; the various facets of hop research and the investigations on Verticillium wilt.

The Committee would like once again to acknowledge its indebtedness to all those who have thus facilitated the extension of the work at East Malling, to the eventual benefit of all.

Scientific Societies and Conferences

Keeping up to date with their special subjects is a ' must ' for all scientists, so, from East Malling, many have been present at regular meetings of the Association of Applied Biologists (A.A.B.), the British Mycological Society (B.M.S.), the Society of Experimental Botany (S.E.B.), the Agricultural Group of the Society of Chemical Industry (S.C.I.) and the Royal Entomological Society (R.E.S.). They were also at conferences of the Horticultural Education Association and meetings of the Institute of Biology.

The Station was also represented at international meetings, on methods for studying high molecular weight carbohydrates (at Edinburgh), the Grassland Congress at Reading, the Bioclimatological Congress in London, and the Symposium on herbicides and the soil at Oxford.

Papers were presented on various occasions : by R. L. Knight with Miss Keep and J. B. Briggs, on breeding for resistance to *Amphorophora rubi*; by M. Allen, on the uptake of magnesium by apple leaves, to the A.A.B. and, at the same meeting, by H. W. B. Barlow and A. P. Preston on fruit thinning apples. R. C. Muir discussed the influence of sprays on the natural control of the fruit tree red spider mite. He also attended the British Association meeting at Cardiff and read a paper, with G. H. L. Dicker, on the control of fruit pests.

H. W. B. Barlow demonstrated an exhibit on the modification of axillary branch form to the S.E.B. and showed a ciné-film on growth inhibitors. D. H. Maggs and C. A. Priestley each read a paper at Nottingham describing results of a shading experiment on young apple trees. E. S. J. Hatcher and R. J. Garner joined in a seminar on vegetative propagation at Nottingham University.

A. F. Posnette and R. S. Pitcher attended, and contributed to, the conference on soil-borne viruses at Dundee. S. C. Pearce and G. H. Freeman both discussed non-orthogonal designs at Birkbeck College. At a conversazione arranged by the B.M.S., P. W. Talboys demonstrated a method of inoculating with *Verticillium* species in host-parasite studies.

The Commonwealth Entomological and the Mycological Conferences both took place in London during the summer. A. F. Posnette chaired a joint meeting on virus diseases and members of staff attended certain of the separate sessions.

The A.R.C. Conference on Insecticides, Fungicides and Weedkillers met for three days at East Malling in March.

Information Services

It is often said that farmers are loath to write letters, and that they much prefer to 'phone. It is true that the Station received many hundreds of telephone calls for information during the past year, but there were also about 1,000 enquiries by post. Possibly fruitgrowers have less aversion than other growers to writing, or the need to send a specimen may, in many cases, have tipped the balance in favour of a letter. Research staff frequently go to fruit farms in the pursuit of specific investigations ; in addition they made 49 visits—sometimes with N.A.A.S. officers—to look into unusual troubles. Thirty lectures have been given to N.F.U. branches, discussion groups, horticultural societies and other clubs in Cambridgeshire, Hampshire, Herefordshire, Nottinghamshire, Suffolk, Surrey and Sussex—as well as in Kent and London. Where the subject was pruning or grafting, a field demonstration was usually given as part of the lecture, or on the day following. Several members of staff assisted with judging fruit and various competitions at fruit shows. G. H. L. Dicker took part in judging the Paddock Wood fruit spraying and orchard management competition.

Every effort is made to keep in personal touch with the advisory officers of the N.A.A.S. and the L.E.A. In addition to the usual day-to-day contacts, they are invited to the regular rehearsals that precede Members' Days, and come for courses arranged specially for them. In all, 244 have visited the Station on these occasions.

The occurrence at the Station of conditions favourable to scab infection (Mills' periods) were

notified regularly to the Maidstone Branch of the N.F.U. Most growers probably applied routine sprays at regular intervals and supplemented these by additional sprays, as necessary, when notified of a severe infection period. Between the end of March and the middle of June ten periods of varying severity were notified.

Exhibits were staged at several shows. At Chelsea and at the Kent Show at Maidstone the importance of an adequate supply of soil moisture was demonstrated, and methods shown of measuring or estimating the moisture deficit and the rate of irrigation to obtain the best results. At Marden, attention was drawn to new apple rootstocks. Some apple and pear varieties were displayed at the R.H.S. Autumn Show. The Station was able to help the N.A.A.S. with material for its exhibit at the Royal Show, and the Central Office of Information with photographs for a portable display for Commonwealth countries.

Visitors

For many years now the Station has been receiving as many visitors as can be looked after properly. Once again the total was just over 2,000—an average of 40 visitors a week if they were evenly distributed throughout the year. In fact, of course, more visitors come in the summer, and those who arrive without previous appointments create complications. Nevertheless, these opportunities of demonstrating the work here and of discussing problems of mutual interest with visitors are very welcome.

As usual, many came in organized parties, amongst which may be specially mentioned fruit-growers from France and Japan and a Finnish Parliamentary Delegation to this country.

It seems rather invidious to pick out particularly distinguished visitors among the 400 who came from overseas, as has been attempted in the past. It is quite clear that all have the interests of horticultural research at heart. It will be as well, however, to acknowledge the implied compliment in the visits of two Ministers of Agriculture, from Victoria, Australia, and from the Eastern Region of Nigeria ; the head of the Programme Directorate who now administer agricultural research in Canada ; the Professor of Horticulture at Michigan University and the Dean of Agriculture from British Columbia ; three Directors of research institutes, from Boskoop and Wilhelminadorp in the Netherlands and from Tanganyika ; and the President of the American Dwarf Tree Association.

Further, when the Review Conference of the Agricultural Bureaux carried out its five-yearly inspection at Bradbourne, the Station was privileged to entertain the delegates representing contributing countries throughout the Commonwealth.

It was an honour to receive Professor H. G. Sanders, Chief Scientific Adviser to our Minister of Agriculture, and useful to have some time with Mr. J. Mellon before he left for Copenhagen, where he is Agricultural Attaché.

The Research Station was included in the programme of visits arranged as part of the tercentenary celebrations of the Royal Society. As the group that arrived was small, it was possible to demonstrate the work in more detail than could have been done to a larger gathering, and a very helpful and stimulating discussion resulted.

Other parties came from the Commonwealth Entomological Conference, the International Society for Bioclimatology and Biometeorology, The Fertilizer Society and the R.H.S. Fruit Group.

Distribution of Experimental Material

If the drought in 1959 affected rootstock production in that year (though it does not seem to have interfered with stoolbed production) the same cannot be said of 1960. However, if the continuous wet weather complicated the harvest, the yield of first-grade rootstocks has been good and, as this is being written, it is possible to add that many of those produced have been taken up.

The Distribution List issued in July 1960 included among the mother trees offered virus-tested selections of Doyenné du Comice pear and Merton Reward cherry, also three plums (bringing the number of virus-tested varieties available of that fruit to ten). Worked trees of thirteen other varieties of fruits were offered, and a list of thirty-seven more—that can be worked on request—was appended. Incidentally, this last facility seems to be much appreciated.

Seven years ago the first virus-tested mother trees (of four cherry varieties) were offered to Members. In 1960 it was possible to offer twenty-one apples, six pears, eighteen cherries and ten plums. The amount of careful, painstaking work that has gone into the collection, testing and production of this wide range of varieties is prodigious. Much of it has been done by the staff of the Pathology Section, but their labours could not have been translated into horticultural practice without the devoted collaboration of the nursery staff.

This season an attempt is being made to let Members have trees surplus to research needs of five

apple varieties on the new M.26 rootstock. Naturally the demand has been heavy, but Members must remember that the primary purpose of the experimental nursery is to produce plants for research and, while every effort is made to share out surplus trees and plants, it is sometimes quite late in the season before the research staff can be certain that they will not need all those that have been propagated for their experiments. So we would ask Members who wish to acquire such plants to be patient and understanding if it is not always possible to supply plants provisionally promised in the early autumn.

Station's Publications

The dissemination of the results of research to fruitgrowers is a matter that the Committee has very much at heart. Generally throughout the country there has been a feeling that this information does not ' get over ' to the grower as readily as it might do. Membership of the East Malling Association and of other similar ones at other institutes is one means of keeping up-to-date.

Initially, research workers generally wish to publish the results of their experiments in a scientific journal, and the form in which they are described—while readily understandable to those with a scientific training—may not always be acceptable to those who have to put these results into practice. Such reports from East Malling are published in the *Journal of Horticultural Science* and in a variety of other scientific journals, while interim accounts of research in progress form Part III of this Annual Report ; during the past year there have been fifty-two of them—full references are given in Part II. The *Journal of Horticultural Science* is published quarterly ; it includes papers not only from East Malling, but from Long Ashton and other horticultural research institutes in the United Kingdom and abroad. On the inside back cover of this Report will be found a summary of the crops and subjects of research on them that are covered in the current Volume 36.

To meet the needs of those who want to know the results but are not particularly concerned with the methods by which they are obtained, bulletins are specially written, appearing generally in the ' popular ' press or in Part IV of this Report (see p. 123). During 1959-60, ten of them appeared (see Part II). In this Report there are three and two specially written summaries of research in progress by R. V. Harris and B. F. Self (see pp. 134, 141).

Library

It has been customary in some past reports to present certain facts and figures about the library, and to compare them with comparable ones presented in earlier years. Information of this sort means very little to readers, who are not personally concerned with the running of a library. In short, it must be conceded that most library reports are excruciatingly dull.

On this occasion it is thought that a better picture of the library may be created by comparing certain of its activities with those of other specialized libraries in the United Kingdom. In particular, a comparison between the loans made by others reveals that the East Malling library is now making an outstanding contribution in this field.

Information on external loans—i.e. items lent to other libraries—is available for 268 specialist libraries co-operating in the National Central Library outlier loans system. Among all these, that at East Malling, with 156 items issued, ranked twelfth. In this it was far ahead of other agricultural research libraries. Moreover, the even more impressive total figure of 552 items lent to outside libraries and institutions takes no account of 359 items borrowed, nor of journal parts handled under the Commonwealth Agricultural Bureaux Pool circulation system, under which 669 items were loaned and 371 borrowed.

External loans are, of course, only part of the story. Within the Research Station, and not counting the Bureau, 3,798 items were loaned to individuals and a further 1,055 journal parts supplied on automatic circulation—in all, 4,853 items.

These few figures are sufficient to justify the claim that here there is a dynamic library that is probably second to none in the service it renders to agricultural research in Britain. Needless to say, with such demands being made upon it, the library continues to grow. During the year under review 114 books, 1,739 bulletins and other pamphlets, as well as many thousands of journal parts and reports, have been added to its stock. Over 530 journal volumes were bound, which necessitated the provision of additional shelving.

RESEARCH REPORT

Part I

THE EXPERIMENTAL FARM

This year will long be remembered by all fruit growers as one of the most difficult and disappointing ever experienced. January and February were very wet and the weather continued cold and inclement throughout the spring. Although there were no severe frosts, conditions for pollinating plums, cherries, and black currants were very poor with cold north-east winds sometimes reaching almost gale force—sufficient to blow some blossom off the cherries. By early May, however, the weather had improved and apple blossom, held back by the earlier cold spell, opened rapidly. Fruit set and development were good, leading to one of the heaviest crops of apples ever recorded. From July onwards frequent heavy rains made the harvesting of cherries and soft fruit difficult and lowered the quality. Two brief hail-storms were sufficient to damage a large proportion of the apple crop. Apple picking, a heavy task in view of the outstanding crop, became a nightmare. Much time was lost because of the rain, all carting was difficult because of the soft ground and, although the season started one week late, apples matured rapidly towards the end of it and many dropped before they could be picked. However, the almost complete absence of the usual equinoctial gales was very welcome.

Although there will be no experimental plantings on the 140 acres of Trust Land before autumn 1961, $57\frac{3}{4}$ acres of it, comprising apples (15 acres), plums ($13\frac{1}{4}$), pears ($5\frac{1}{2}$), black currants ($7\frac{1}{4}$) and arable ($16\frac{3}{4}$) were farmed during the year. Nineteen acres of apples and plums were cleared and put under arable crops in 1960 ; the remainder amounting to $22\frac{1}{4}$ acres under fruit is being retained for the present, the pears and black currants in particular being in full cropping.

Experimental orchards

Top fruits

Apples.—The total crop of apples of all varieties harvested in 1960 was 350 tons, almost 100 tons more than in 1959 and the heaviest since the grubbing of older plantations no longer of experimental value was started in 1947. But whereas in 1947 culinary varieties comprised considerably over half the total production, in 1960 these accounted for less than a quarter of the crop. It is also noteworthy that the severe drought in autumn 1959 seems to have had little effect on the performance of the trees in 1960. There was some tip dieback particularly on Sunset, Egremont Russet and Ribston Pippin, but even on the lighter Larkfield soil trees which had wilted badly for some weeks in 1959 fruited well.

All varieties cropped heavily except Lane's Prince Albert. This variety set well and the fruitlets were therefore thinned, though rather late ; a fortnight later there was a heavy ' June drop '. Our other main culinary variety, Bramley's Seedling, bore a heavy crop of good quality fruit for the third year in succession. The yields from 1958-60 have been 31, 39, and 34 tons from about 150 trees. At 48 trees to the acre this works out at a 3-year average of about 12 tons per acre—which is good even for trees of a heavy cropping variety. At 86 tons, Cox's Orange Pippin doubled the 1959 crop, producing more apples than ever before in the Station's history. As all trees bore so well and fruit size was satisfactory it was sad that so much of it was marred by hail damage. On only one plot (P10) on rather thin soil was it necessary to thin the fruit. The 31-year-old Cox's Orange Pippin on M.XII in the manurial trial on Churchfields bore well for the second year in succession and the 40-year-old trees on Kiln Field (K2), which have not yielded profitable crops for some years, also did well. Of the younger plantations the 9-year-old trees on M.VII in Deadman Field did particularly well, averaging 165 lb of excellent quality fruit per tree. The total crop of Worcester Pearmain was somewhat less than in 1959 possibly because, where experimental treatments allowed, all trees of this variety were heavily thinned in good time to increase fruit size. Results were excellent, size was good and the frequent

showers seem to have given exceptionally good fruit colour. Trees of Ellison's Orange set heavy crops and, these fruitlets having been thinned early, fruit of good size was obtained. This variety tends to be biennial, but this severe thinning should help to produce a better crop in 1961. Jonathan trees again cropped well, as did those of Laxton's Superb which were in an 'on' year. Unfortunately, experimental requirements did not permit much fruit thinning and there was much small fruit so that, in spite of propping, breakage of many branches resulted. Trees of Late Orange behaved similarly, underlining the necessity for thinning this variety in heavy cropping years.

Pears.—The 1960 pear crop was a good one, 23 tons as against 16½ in 1959. All varieties blossomed profusely, but inclement weather caused much cracking and russeting of Conference and there were many poorly shaped fruits. Williams' Bon Chrétien, which blossomed a day or so later, whilst showing some russeting did not split as did Conference and trees of this variety bore good crops of large fruit on the experimental plots. On the Trust Land, only 40 ft lower in elevation, cold air accumulated on the night of 2nd May killing many blossoms and greatly reducing the crop of Williams'. However, this plantation (Scott) contains a mixture of varieties some of which must have been at a less vulnerable stage and the total yield was 16 tons from approximately 5 acres. Doyenné du Comice escaped the frost and did particularly well all over the farm.

Cherries.—In the last year before grubbing the 6½ acres of 35-year-old cherry trees again bore only a light crop (19 tons). Although poor weather at blossoming undoubtedly played its part, disease, particularly the after effects of the virus trials, probably accounted for most of this, many trees having in recent years borne very little fruit. Moreover, the rain interfered seriously with picking and many fruits of all varieties split badly. Fortunately the young trees planted in Newgates Field in 1954 and 1955 have grown well and are just beginning to bear worth-while crops. There have so far been no losses from bacterial canker and the crops from these trees will soon replace those from the older plantation.

Plums.—As in other parts of Kent the plum crop was negligible, only 4¾ tons or about one eighth of that in 1959. There was little blossom and what there was set poorly. The only varieties to produce worth-while crops were Czar and Marjorie's Seedling.

Soft fruits

The acreage of strawberries was again small and only just over 1 ton of fruit was sold. In this season Verticillium wilt was severe on many of the experimental plots. It seems that, until some means of control can be found, only by growing resistant varieties can experiments be continued, so that the acreage is likely to remain small.

The raspberry crop was again good, both our main varieties yielding well, and there was little trouble with Botrytis even though many fruits became overripe when the weather interfered with picking. The two acres of Norfolk Giant and Exploit planted in 1955 has so far cropped as follows:

Yield of fruit in tons per acre

	Exploit	Norfolk Giant
1957	½	½
1958	3½	4
1959	5½	4
1960	4	5½
	13½	14

The poor weather badly affected the set of black currants all over the farm. Most of the 4½ ton crop from some 3½ acres of experimental plots came from about 450 bushes of Amos Black in the irrigation and nitrogen trial on Egham Field (E27). This variety flowered later than other varieties, so that some plants yielded as much as 20 lb per bush.

Fruit marketing

As the coming glut of apples was obvious early in the year every effort was made to produce fruit of good size and quality, sometimes even at the expense of total crop weight. Where experimental treatments allowed, all varieties were heavily thinned, while contracts were made early in the season to dispose of as much sub-standard fruit as possible. Unfortunately, the apples suffered hail damage for the third year in succession resulting in down-grading of much otherwise excellent fruit. All the Worcesters were marketed at picking time and the better grades made fair prices. Ellison's Orange, however, at the height of the season became almost unsaleable. Approximately half the apples were

cold-stored until the space was wanted for later varieties, by which time prices had improved slightly. The Lane's Prince Albert were also marketed as soon as picked and as the fruit was large it realized a fair price, and the storage space was filled with the more valuable Laxton's Superb and Barnack Beauty for long keeping. The crop of Bramley's Seedling, except for the very small fruits which were sold for peeling, will be kept in gas store until March 1961. Both the small stores are full of Cox's Orange Pippin, kept at 36° F in an atmosphere containing 3% oxygen and 0·5% CO_2. It is proposed to open these stores in mid-February.

The bulk of the raspberries were again sold for processing but prices were down considerably on 1959, due partly to a heavy carry-over of pulp. The marketing of plums and black currants presented no difficulty as both were in short supply. Marjorie's Seedling plums marketed in 12 lb trays made up to 1s. 5d. per lb and black currants in 1 lb punnets between 1s. 9d. and 2s. 6d.

Fresh planting and grubbing

Planting plans for 1960/61 have been seriously held up by the weather. Three and a half acres of Egremont Russet and James Grieve apple on M.26 will be planted on Park Farm (P14) for ecological work and 1¼ acres of Cox's Orange Pippin, Worcester Pearmain, and Egremont Russet on M.VII in Kiln Field (K6) for fruit nutrition studies. Also on Kiln Field (K4) 2 acres of Cox's Orange Pippin and Worcester Pearmain on M.26 will be planted at 12 ft square to make small compact trees for general experimental use as required. In addition, 1¾ acres of apple trees and rootstocks will be planted closely in Egham Field (E29) for various intensive experiments. Also on Egham Field (E27) a trial will be started to test the effect on apple trees of different intermediate stempieces. A small area of strawberries will be planted on Newgates Field for work on Botrytis.

The 35-year-old cherry orchard (C4) was grubbed in autumn 1960. The old plum variety collection on Egham Field (E34) has also come to the end of its useful life and as there are several areas of young plums coming into bearing the trees here will also be cleared, as will the small cherry double-working trial (E28). On Great East Field small areas of raspberry seedlings (G18) and of apple rootstocks in a virus experiment will also be cleared.

Routine spray programme

There is now such a wide range of chemicals and many of them are so effective that the need for a ' routine spray programme ' applied over all as an insurance is rapidly diminishing. This is particularly so as regards insect pests for, by keeping a sharp look-out and spraying at the first sign of damage, the necessity for costly and laborious winter washing can be virtually eliminated. With fungal attacks also careful timing can do something to reduce the numbers of spray applications required. At East Malling, winter washing is now largely confined to nursery material and young trees where the distortion of a single shoot by aphid attack can seriously interfere with the results of an experiment. Plum plantations were sprayed with 5% tar oil during December 1959 with a view to reducing the amount of spraying to be done in the busy spring period. Only where there had been a mildew problem in the past, were some of the apples sprayed with DNC.

Showers and high winds interfered badly with scab control, and the pre-blossom application of captan/karathane mixture which, with the addition of two lime-sulphur sprays, has proved so successful in the past, had to be omitted. However, conditions improved somewhat in May and June and all varieties were sprayed five times after blossoming, dessert, varieties with captan/karathane mixture and Bramley's Seedling with lime-sulphur. There were some early scab infections but no serious outbreak. The incidence of mildew was further reduced and the foliage looked healthy throughout the season. Metasystox was added to the green-cluster scab spray for the control of aphid and at petal-fall against red spider. Phenkaptone was applied three weeks after petal-fall and this effectively prevented a late build-up of spider. Three applications of lead arsenate were used against codling moth, 10 days after petal-fall, the 3rd week of June, and the 2nd week of July. Losses from this pest were less than in 1959, but control was not complete.

Five high volume applications of 2% Epsom salt prevented the occurrence of magnesium deficiency symptoms which have been evident on certain trees for some years.

The pear spraying programme was similar to 1959 except that instead of lime-sulphur pre-blossom and captan post-blossom, the latter was used throughout the season for scab control on Doyenné du Comice. There was a fairly severe attack of Bryobia mite on the mixed plantation on Scott field but this was easily dealt with by a single application of metasystox. Similar measures soon cleared up an outbreak of aphids on Conference (E36). Young plums were sprayed with a preparation containing 15% copper oxychloride for control of bacteriosis, three weeks after petal-fall and again three weeks later. Metasystox at 12 oz per 100 gal. was added to the second spray for the control of red spider and aphids. The effective cherry spraying programme was the same as in 1959.

Rather more raspberry spraying was done this year ; in addition to the bud-burst application of lime-sulphur and DDT for cane spot and aphids, Malling Jewel was sprayed during the second and fourth weeks of May with 2 lb BHC against cane midge, as this pest had caused slight damage and loss of cane in 1959. Malathion at 16 oz per 100 gal. was used against raspberry beetle at the pink fruit stage in 1960 and seemed rather more effective than the liquid derris used in the past. Black currants were again sprayed with endrin at 1½ pt per 100 gal. against big bud mite, when the first blossoms were open. For aphid control, DDT was added to this spray but, this proving ineffective, metasystox was applied a month later. An application of 4:6:100 Bordeaux mixture plus 6 pints of cotton seed oil directly after picking again greatly reduced leaf spot. All fruiting strawberries were given six sprays, four before fruiting and two after. Thus, in late April 3 pt of colloidal sulphur, 8 oz of metasystox and 5 pt of aldrin per 100 gal. were applied to control mildew, aphids and seed eating beetle ; two sulphur dustings were given to control mildew, and 5 lb captan per 100 gal. against Botrytis. After fruiting, all beds were sprayed twice with a mixture of colloidal sulphur and metasystox.

Arable crops

Including the Trust Land, there was an area of 140¼ acres under arable crops. Heavy rain in November and December 1959 prevented as much deep ploughing and cleaning as had been hoped and some of the Trust Land was sown under rather unfavourable conditions. The appalling weather at harvest time further added to our difficulties and only the most strenuous efforts by all members of the farm staff enabled satisfactory results to be achieved.

Thirty-eight Hereford steers were again yarded from the end of October until the Maidstone Fair on 13th May and trod some 120 tons of straw into dung. This dung is not of very high quality but is more uniform than can be bought.

Potatoes.—10 acres of Craig's Royal, 2 of Stormont 480 and 16½ of Majestic were grown. The ample moisture made all varieties grow strongly but also encouraged blight and, in spite of three sprays, the haulm had to be burnt off early in September in order to prevent tuber infection. Further, presumably because of the prevalence of aphids in 1959, much of the once grown seed and some of the new appeared to be infected with virus. These two factors reduced yields. Harvesting of the later varieties was exceedingly difficult but was completed by the end of November ; towards the end, however, it was impossible to distinguish mud from tuber, and many tubers were left in the ground.

The yield of 7 acres of Craig's Royal, harvested and marketed in August, was satisfactory, but prices were very poor. The Stormont 480 and Majestic were lifted in October and November and the majority stored in the tythe barn at Bradbourne which with its thick frost-proof walls makes an ideal potato store. The Stormont 480 did not prove as blight resistant as expected and some Majestic were also infected; however, the crop was heavy and the proportion of damaged tubers was not large.

Peas.—The acreage of peas grown for canning and quick freezing was increased from the 20 acres grown in previous years to 35, and the variety Dark Skin Perfection was grown for the first time. About half was sprayed with a residual herbicide and half with DNBP for weed control, rather high rates of the latter being used on some of the Trust Land because of heavy weed growth. Although it looked at one time as though both the peas and the weeds had been killed, the crop recovered remarkably well and all weeds, except docks and couch, were completely controlled.

An overdose of herbicide probably somewhat reduced the yield of Surprise but other varieties more than made up. Kelvedon Wonder yielded 54 cwt per acre, Dark Skin Perfection 53 cwt, Perfected Freezer 41 cwt, and Lincoln 39 cwt per acre. After the peas were harvested some of the ground was rotavated four times to clean the land and most of the docks and couch were eliminated despite the wet weather. Other fields were sprayed with a preparation containing amino-trizole which killed the couch and larger docks, although many dock seeds have germinated since.

Cereals.—Of 49½ acres of wheat grown, 24½ consisted of Cappelle and the remainder Jufy 1, a recent introduction from Belgium reputed to be heavier yielding than Svenno and Atlé, athough the grain is not of such good quality. The yield of Jufy 1 was approximately 26 cwt per acre and there was no trouble from lodging or sprouting. This compares with an average yield of 30 cwt per acre from Svenno in the exceptionally good year of 1959. The 24½ acres of Cappelle averaged 34 cwt in 1960 compared with just over 2 tons in 1959. During August it rained on 22 days, but although harvesting was slow and expensive, the combine harvester and grain drier enabled us to get all the corn in by the first week in September.

Seventeen acres of clover and ryegrass were grown for hay and silage and 4½ acres of 3-year ley and 5 acres of roots and kale for feeding the horses and bullocks. In addition, 120 tons of pea haulm were collected from the viner and ensiled. Pea haulm makes a rather moist, medium quality silage which though perhaps not ideal for dairy cattle is well suited to the type of stores kept here.

Experimental nurseries

Some twenty thousand rootstocks were lined out on the south end of Ditton Fields in autumn 1958 and spring 1959 for budding and grafting to form the maiden nursery of 1960. In view of the poor and uneven growth on the northern part of this field caused by the previous use of this land as a stoolbed the 1960 nursery was planned so that pome fruit trees followed stone fruits and *vice versa*. In consequence growth of maiden trees in 1960 was excellent. Moreover, there was little trouble from pests or diseases and two applications of metasystox and one of phenkaptone gave complete control of red spider. The number of stocks lined out may seem large but not only is material required for use on this Station, but also many trees are raised for trials on growers' farms, for other research institutes, for intensive laboratory trials, for nursery compatibility trials, and for virus indexing.

A further five varieties were added to the range of Mother Trees available—Doyenné du Comice pear, Merton Reward cherry, and Yellow Egg (Pershore), Czar, and Prune Damson plums.

The wet weather seems to have suited the stoolbeds, for almost all types of rootstock yielded above the average number of rooted shoots. Weed control and earthing up of the stools was hampered by the wet conditions but mildew was less troublesome than usual. The mild open autumn delayed leaf-fall, and soil conditions were so bad at the time of unearthing the stools that it was impossible to complete the harvesting of rootstocks until well after Christmas, with consequent delay in dispatching Members' orders. Attempts are being made to find a defoliant which will not cause damage and some promising results have been obtained. If further trials prove successful it will be possible to start harvesting rootstocks earlier in the season when soil conditions are better.

Experimental glasshouses

One of the main considerations in the experimental glasshouses is the lowering of excessive summer temperatures, and various methods have been tried from time to time. In some houses it has not been possible to reduce the temperature sufficiently by the usual methods of manual ventilation, blinds and shading. This, however, has now been achieved successfully by means of fans and water sprays, some of which were manually controlled while others were automatic.

A project undertaken during the winter associated with this idea involved rebuilding and enlarging a glasshouse. A fan, controlled by an air thermostat near the centre of the house, was installed to enable cool moistened air to be drawn through the house from two small chambers at the opposite end where it is saturated by means of a number of nozzles. This equipment, together with fabric blinds on the roof, sides and south end, has enabled the inside temperature to be maintained at approximately 7° F above the outside screen temperature on sunny days. This is the most efficient of the simple systems so far tried.

A somewhat less efficient and less versatile system employing heat absorbing glass on the roof instead of blinds has maintained a temperature up to 10° F above the outside screen temperature.

Another method of lowering excessive glasshouse temperatures, involving a water mist on the roof, has given interesting preliminary results. The main difficulty is in obtaining even distribution of mist, but this has been largely overcome by the use of a permanent screen of fabric raised a few inches above the glass.

A trial is being made of a new type of house 20 × 10 ft, using galvanized iron for the framework and a translucent corrugated polyester in place of glass. This house is orientated approximately east-west. Since there is little obstruction from the supporting framework and no overlaps, the amount of light received inside should be greater and heat loss in winter reduced compared with an orthodox glasshouse, while during the summer, shading should be unnecessary.

The indoor mist propagation equipment has been extended and the quantity of water reduced by means of a more efficient hydrostat. A much finer rooting medium is now being used and tests are being carried out on the usefulness of other media, size of cut or wound, and concentration and quantity of rooting substance.

The small chamber constructed during the previous year for use in apple scab studies has been modified and humidity is now controlled automatically by means of a hydrostat. Provision has been made to override this control and increase the moisture content of the air manually, if necessary.

The amount of work carried out in the winter continues to increase and, to enable plants to be grown satisfactorily, additional supplementary illumination has been installed. The use of 2 and 3 in. expendable pots has increased since they do not have to be washed, sterilized and stored. The numbers of 3 to 11 in. non-porous pots have also increased and have proved generally satisfactory ; they have considerably eased the labour involved in day to day watering, and cleaning has been simplified due to their smooth, non-porous surface. As part of an endeavour to reduce the juvenile phase in rootstocks, it was found possible to grow them in two distinct phases in any one period of twelve consecutive

months. Unfortunately, subsequent growth and development was poor and it was decided to grow the trees normally for one year before continuing the treatment.

The number of spray applications remains fairly constant, although the use of systemic insecticides where possible reduces this figure. Tedion has been used against red spider mite this year for the first time and has been quite effective. The old remedy of washing soda with a wetter still proves the most effective material against mildew on gooseberry and currant seedlings under glass.

The method of subjecting trees to a period of cold prior to forcing them in the spring, and retarding rootstocks till June at 38° to 40° F is now standard practice, and the number of plants treated in this way continues to increase.

Although there are now fewer apple seedlings, the total number of seedlings has increased because there are more of raspberry and currant. In addition, more rooted cuttings, especially of hops, are now produced each year.

Part II

GENERAL REVIEW OF RESEARCH WORK

WITH LISTS OF PAPERS PUBLISHED DURING THE YEAR

I. POMOLOGY

Tree fruits

Blossom was abundant ; and spring weather conditions were good for apples, though bad for plums. Yields of apples were high, and in spite of low sunshine fruit colour was good.

Rootstocks

The Malling-Merton rootstock trials are now 15 years old. As previous rootstock trials have shown that the order of vigour is unlikely to change after this age, a comprehensive report is now being prepared. A tour of 33 demonstration plots of Malling and MM. rootstocks, in various parts of the country, was made. On 27 of these plots the trees are now 6 to 9 years old, and their performance so far is generally similar to that at Malling, though some signs of special suitabilities for different soils are beginning to show. Those giving a good performance on a wide range of soils include MM.106, MM.111 and M.XXV.

A trial of quince rootstocks for pears was planted, comparing 5 quinces from the Caucasus, 2 from Provence, 1 from Angers and 1 from South America with Quince A. The scions are Conference and Beurré Hardy. Previous small-scale trials suggest that the Caucasian quinces are less vigorous, and the others more vigorous, than Quince A.

Some clonal selections from open-pollinated seedlings of St. Julien d'Orleans plum include a wide range of vigour, and propagate readily from cuttings. Some also show high resistance to bacterial canker (see p. 24). Material is being raised for compatibility tests with plum, peach, and apricot. Compatibility tests are in progress with two virus-tested selections from *Prunus domestica* and two from *Prunus insititia*.

Some ready-rooting clonal selections from seed of *Pyrus communis* collected in the Ankara district of Turkey appear to be compatible with the variety Williams' Bon Chrétien.

Interstocks.—A trial of the use of interstocks (intermediate stem-pieces) for apples has been planted. The scion is Cox's Orange Pippin, the rootstock M.II, and the interstocks M.IX, M.VII, M.26, M.II, 3428, 3430 and Crab C, in 2 in. and 14 in. lengths. These extremes of vigour and length of interstock will provide for a study of fundamental effects. Trees for a further trial, of various dwarfing interstocks on the vigorous and well-anchored MM.104 rootstock, have been prepared for planting in autumn 1960. If it is possible to combine dwarfing with good anchorage in this way, the trouble and expense of staking might be avoided ; but previous experience suggests that the degree of dwarfing will be less than with dwarfing rootstocks.

Incompatibility

It has been confirmed that incompatibility between Hale's Early peach and Myrobalan B can be induced across a 4 in. intermediate stem piece of the mutually compatible rootstock Brompton. The Myrobalan B tissue was introduced in the form of a bark ring, and bridging of this ring did not reduce the incompatibility symptoms in the peach scion. Patch-grafts of Myrobalan B containing a dormant bud increased the crop weight without reducing the size of 5-year-old trees of Hale's Early on Brompton.

The incompatibility which develops in the presence of the variety Victoria between Myrobalan B and the plum variety President has been investigated in a series of small-scale trials. It has been found that unions between President and Myrobalan B were defective in any tree containing the variety Victoria as a third graft component, whether in the position of rootstock or top-scion. There was no evidence that the induced incompatibility between President and Myrobalan B was graft transmissible, but it was confirmed that the two varieties President and Victoria are not fully compatible (see p. 57).

A review of graft-incompatibility with special reference to its possible causes is in preparation.

Histology

Varietal differences in cuticle thickness, stomatal frequency, the shape of cells of the palisade parenchyma, and in the relative depths of the palisade and spongy mesophyll tissues are being examined in leaves of apple, plum and cherry.

Observations are in progress on modifications in structure with ageing, in plum and cherry. Previous work on apples has indicated that inherent anatomical differences, i.e. those between varieties, usually become more strongly marked with increasing age of the individual tree.

Changes in vessel size across successive annual rings are being followed in roots and stems of plum and cherry rootstocks, and the changes related to rootstock effect on scion growth.

A paper on rootstock-scion interaction in apples with special reference to root anatomy, and a short note on vessel structure in the xylem of roots of M.XVI apple rootstock are in the press.

An investigation of structure in relation to the capacity for adventitious rooting has been continued on dormant stems, and extended to include developing stems used as softwood cuttings.

A collaborative experiment with the Entomology Section has been begun on resistance mechanisms to the woolly aphid, *Eriosoma lanigerum* Hausm (see p. 33).

Histological studies of skin finish, including russeting and cracking, have been continued (see p. 9).

Propagation

The first year of the new large-scale trial of budding cuttings in the year of planting has demonstrated that the plum rootstocks Myrobalan B and Brompton can be successfully handled in this way. The apple rootstocks M.26 and MM.104 were unsuccessful this year : failure was in part due to planting on land previously used for apple stoolbeds, once again proving that replanting has its dangers, but heavy rain during storage also led to some loss of condition at planting.

Under mist, long (16 in.) cuttings of M.26 have rooted well and have been transferred to the open nursery under sprinklers. Provided they overwinter satisfactorily it should be possible to bud them some twelve months from taking the cuttings.

A trial of adventitious and normal shoots, as cuttings, showed that the former rooted more readily than the latter. Trees raised from scions of such shoots now show that adventitious shoots form trees that are relatively slow to flower. This is further evidence of antagonism between fruiting and rooting propensities (see p. 52).

Nursery testing of rootstocks has continued and selections made for larger-scale propagation and testing. Six out of an original hundred *Pyrus calleryana* pear seedlings have been retained and the number of *P. communis* selections has been drastically reduced. Further compatibility tests have been made between sweet cherry scions and a range of *Prunus* species and hybrids. A further series of trees with intermediate stems likely to restrict vigour are under construction. Some earlier indications of reduced vigour, on mahaleb and on acid cherry, are now seen to have been associated with the presence of necrotic ring spot virus.

Further studies of mid-July and late August budding of apples show that swelling of the rootstock is greater following early than following late budding, and the risk of constriction by the tie is correspondingly greater ; this appears to be a possible cause of the delayed bud-break in the following spring, noted with early-budded apples.

Budding apples at 12 in. from ground level, to avoid collar rot, has also been found to produce better maiden trees (see p. 49).

Root studies

Experimental trees with split root systems have again been used to investigate seasonal changes in the absorptive capacity of roots. Observations were continued on the seasonal pattern of root growth of apple trees in the orchard, using root observation trenches. Histological studies were made on the absorbing regions of apple and plum roots.

The construction of an underground root investigation laboratory was started. It is planned to plant the experimental material for this project in the winter of 1960-61.

A review of work on fruit tree roots was published (E526).

Anchorage

An experiment has been planted to test the suggestion that if dwarfing rootstocks are grafted higher and planted deeper than usual, staking will not be needed. Trees of Cox on M.VII, budded at 6 and 12 in. above soil level, have been planted out with all the unions at 6 in. above ground and with no stakes. Records of tree growth, any leaning, and eventually of firmness of anchorage, will be made.

Pruning and tree shaping

In the apple pruning trials, now 15 years old, fruit thinning treatments have been superimposed on the original treatments of Worcester Pearmain and Laxton's Superb. In addition, the Laxton's Superb and Cox's Orange Pippin trees are now pruned either annually or in alternate years, to see if the labour of pruning can be reduced without affecting fruit yield and quality. A paper (E521), a review (E533) and a Growers' Bulletin (E520) were published, and a paper was given at the centenary celebrations of the Institute of Agriculture and Horticulture, Gembloux, Belgium.

Fruit thinning

In the collaborative experiment with the Physiology Section, on different degrees and times of thinning Sunset apple, records were made of residual effects of the treatments that were ended last year. A report is in preparation. As mentioned above, thinning treatments have been begun on the apple pruning trials.

Biennial bearing and analysis of fruiting

In a new trial of defoliating sprays the same treatments were applied to two orchards of Laxton's Superb on the same day. Differences between the two orchards in response to some of the treatments are being studied in relation to tree growth and the development of the spur buds. A paper on the earlier trials has been published (E524).

Studies of seasonal effects upon fruit bud formation show that the rate of development of the buds in off-year trees, has been similar for several years. The pattern of development following defoliation is similar in all treatments, and the ability of the bud to become a fruit bud is related therefore to the time in the season when it began to form. This, in turn, appears to be related to the expansion of the foliage.

The effect of fruit upon the development of buds is also being investigated. In the biennial variety Miller's Seedling the rate of bud development, from the beginning of June until the end of the season, is slower in the presence of fruits than in the absence of fruits. This effect is being studied further.

Experiments on factors which may influence fertility and fruit setting are being continued.

Skin finish

A preliminary study of russet and non-russet apples has shown a relation between the anatomy of the skin and the tendency of the fruit to russet. In true russet varieties the hypodermis is composed of thick-walled cells, and cutin often extends between the radial walls of the epidermal cells forming peg-like outgrowths and sometimes completely surrounding the cell thus forming a double cuticle. Not only are differences in the anatomy of the dermal tissues related to russeting ' potential ' as between different varieties, but also within a single fruit—the stalk and eye ends of the fruit, where the hypodermal cell walls are thickest, being especially prone to russeting.

Measurements of the distribution of growth over the fruit are now being analysed to study the development of shape in relation to cracking in Cox's Orange Pippin. Two preliminary experiments support the theory that wet, humid weather increases russeting and cracking.

It has been observed that cracking and russeting of Cox's Orange Pippin are more frequent on poorly grown trees having an inadequate leaf cover. These two factors are also being studied.

Weedkillers

Simazine at 2½ and 5 lb per acre and monuron at 5 and 10 lb per acre respectively have been applied to a range of young apples and pears. In the year following application, one pear tree has shown signs of monuron injury, but no other damage has appeared, and weed control has been very good.

Experiments with diquat and with maleic hydrazide have been continued.

Breeding

Some 250 of the apple seedlings, bred between 1953 and 1959 to combine late flowering with high quality, have now borne their first fruits. Over two thousand have yet to fruit. Further families were raised, from crosses designed to provide early maturing fruits and russets.

Work has been started on a long-term programme of a more fundamental nature. A major gene for apple scab resistance, derived from *Malus floribunda* by workers in America, is being transferred to varieties of English origin with a view to its ultimate incorporation into some of the material raised at East Malling. Sources of major genes for apple mildew resistance are also being sought.

Several crosses between Northern Spy and rootstock varieties, both resistant and susceptible to the woolly aphid, have been made for histological and entomological studies.

Of about 1,200 cherry seedlings from crosses between selected Mazzard clones, from which it is hoped to select improved cherry rootstocks, about two-thirds have proved susceptible after inoculation with Bacterial Canker. Those that have shown resistance are being subjected to further test ; those selected will then be screened on the basis of their root anatomy.

Varieties and clones

Owing to frost and cold winds during and immediately after blossoming, few plums carried more than light crops this year. Bountiful averaged 50 lb per tree, Comte d'Althann's 35 lb, Ontario 30 lb, and Warwickshire Drooper and Victoria only 10 lb. However, a seedling raised here, E296, carried 300 lb per tree. This variety leafs out with the flowers, and the leaves afford some protection to the flowers.

Small fruits

Variety and strain trials

Strawberries.—Cambridge Favourite again gave the highest yield (5½ tons per acre) in a trial comparing eight leading commercial varieties. The production of secondary inflorescences was very marked in this variety this year ; these later opening trusses also produced large fruits. Blossom abnormality was again prominent in the variety Redgauntlet.

A study of the effects of reduction in virus content in clones of Cambridge Favourite and Early Cambridge showed that heat-treated plants of both varieties were not only more vigorous in terms of height and spread but that they also had more crowns.

In two trials comparing three strains each of the varieties Royal Sovereign and Sir Joseph Paxton, Botrytis severely reduced yields, making comparisons difficult.

Loganberries.—The first crop was harvested from a trial of virus-tested loganberry clones which includes the sub-clone LY59 now included in the Ministry of Agriculture's certification scheme. All clones cropped exceptionally heavily for maiden plants, yields averaging 12 lb per plant (about 4 tons per acre).

A curious abnormality was observed in some fruits of all five clones in an older trial ; in many of the early and mid-season fruits numerous druplets failed to swell, resulting in short uneven berries. This trouble may be associated with damage to the tips of young canes, which caused extensive branching. Although no very severe frosts were experienced this spring, it is thought that both these abnormalities may be a consequence of low temperature injury. Two papers were published, E515 and E522.

Blackberries.—The trial comparing a thornless sport of Bedford Giant with a normal thorned selection of the same variety bore its maiden crop. Both clones yielded about 30 lb per plant (about 10 tons per acre), from plants that were close planted, and trained by the weaving method.

Propagation and maintenance of stocks

Strawberries.—Thirty-six strains and clones were multiplied in gauzehouses including seven clones of Climax which have remained free from ' yellows ' since their initial propagation two years ago. As usual a nucleus of nearly fifty varieties was maintained in an insect-proof glasshouse ; and material for field trials was raised in isolated runner beds.

Black and hybrid berries.—Several clones were propagated both by tips and leaf-bud cuttings to provide for future trials.

Breeding

Raspberries.—Remarkable firmness of fruit has been shown by certain selections obtained by backcrossing American black raspberries to reds. A further backcross generation has now fruited ; some of these plants combine good fruit quality with outstanding firmness. Crosses have now been made to combine these qualities with spinelessness and aphid resistance.

Breeding for resistance to *Amphorophora rubi* was continued, in collaboration with the Entomology Section, and a further paper on the inheritance of resistance was published (E523).

A number of crosses were made between inbred parent lines as a first step in the production of commercial varieties.

Hybrids of raspberry with *R. arcticus, R. glaucus, R. mesogaeus,* and *R. cockburnianus* were raised.

Currants.—Tetraploid black currant–gooseberry crossed with diploid and tetraploid black currant

flowered sparsely for the first time this year. Several of these were included in preliminary trials for big bud mite resistance, made in collaboration with the Entomology Section.

A survey was made for gooseberry sawfly resistance in *Ribes* species and hybrids and cultivated forms.

Gooseberry.—A number of hybrids of B21 (tetraploid black currant-gooseberry) × tetraploid gooseberry were raised and proved to be spineless, apart from soft spines at the base of young seedlings. Further triploid hybrids of B21 × diploid gooseberry parentage were also grown.

Twenty-one first generation selfs and ten second generation selfs of gooseberry were grown; included in these were 16 selfs of commercial varieties raised from seed kindly supplied by Long Ashton. Several allotetraploid species hybrids were received from Professors Bauer and Nilsson during the year, in exchange for material bred at this Station.

Cultural measures

Strawberries.—A collaborative trial with the Fruit Nutrition section was laid down to study the effects of dung and annual applications of inorganic nitrogen. In particular it is hoped to study 'blindness' in relation to plant vigour.

A trial of early planting, using runners of the variety Redgauntlet, kept in a cold store at 30° F since February, was planted in July. Freshly dug runners were planted at the same time for comparison.

Weedkillers

Black currants.—Simazine at 2½ and 5 lb per acre again caused no reduction in growth or yield, whilst monuron at 5 lb per acre reduced both growth and yield. Damage from monuron at 10 lb per acre the previous year was so severe that this treatment was not repeated.

Raspberries.—Simazine has again given no adverse effects, whilst after a second application of monuron damage has been much increased, so that the 10 lb per acre monuron treatment will not be repeated.

Frost damage investigations

Protection of black currants from frost by water sprinkling was investigated in autumn 1959 and spring 1960. In autumn the rest period of the bushes was broken with gibberellic acid and flowering bushes in pots were exposed to natural frost conditions down to 22° F. Frost protection of isolated bushes required precipitation rates of 4 to 5 mm/hr, but when a whole plantation is sprinkled lower precipitation rates are expected to be effective. This is supported by some growers' experiences this spring.

On 26th/27th April 1960, the air temperature on the frost plot fell to 26° F. Frost damage to black currants was general and their crop greatly reduced. Amos Black again proved more resistant. This spring, tying up bushes greatly reduced the frost damage inside the bushes, but it is evident that the ties must be released before the leaves have grown much.

All pear varieties were severely damaged on the frost plot. A single application of gibberellic acid (50 p.p.m.), one day after the frost, resulted in a bumper crop of good sized seedless fruits on Conference. Gibberellic acid applied to decapitated white buds (styles, stamens and petals cut off) of Conference and Laxton's Superb one day after frost, caused them to set a heavy crop of marketable seedless fruits. Treatment of frozen pear blossoms with GA may have commercial possibilities (see p. 46).

Frost damage to apples was negligible and crops were heavy, though badly marked by the July hail. Varieties differed in response to it, some cracking, others hardly showing any marking. Frost damage on all plum varieties was very severe. Only Pershore and Czar produced a small crop. Cherries suffered little damage except for one variety, Noir de Guben.

In the frost rooms frost resistance tests of certain varieties and new seedlings were continued. Two black currant varieties, Brödtorp (Finland) and Consort (Canada) reputed to be spring frost resistant, were tested together with Wellington XXX at grape and open flower stages.

Laboratory experiments also included a study of the effect of gibberellic acid on fruit development of frost damaged blossom in apples and pears.

The use of gibberellic acid sprays in autumn and NAA in spring to delay blossoming of Cox's Orange Pippin was not successful.

A paper on 'Breaking the rest period in black currants with gibberellic acid and low temperature' is in the press.

Mycorrhiza

Dr. Mosse has been seconded to the Soil Microbiology Department of Rothamsted Experimental Station, where she is continuing her work on mycorrhiza.

Walnuts

Following the hot summer of 1959, there was plenty of blossom, and much of it escaped frost damage in the spring. Crops were moderate in amount, but many varieties failed to ripen properly and had imperfectly developed shells.

Horticultural meteorology

The usual meteorological records were maintained.

Our hail gauge recorded hail equal to about 0·04 in. of rain on 12th July, during a thunderstorm of rain and hail in which a total precipitation of 0·47 in. fell in 30 minutes. This hail damaged many apples. There was also 0·01 in. of hail on 1st August. In both storms the hail was estimated (visually) to be 5–9 mm diam.

A report on wind studies on plots of differently spaced trees in an exposed apple orchard was published (E516).

Publications during the year

E512 Mosse, Barbara M. (1959). **The regular germination of resting spores and some observations on the growth requirements of an *Endogone* sp. causing vesicular-arbuscular mycorrhiza.** *Trans. Brit. mycol. Soc.*, **42**, 275-86.

E513 ——— (1959). **Observations on the extra-matrical mycelium of a vesicular-arbuscular endophyte.** *Trans. Brit. mycol. Soc.*, **42**, 439-48.

E515 Beakbane, A. Beryl, and Labern, M. V. (1960). **The performance of some virus-tested loganberry clones.** *Rep. E. Malling Res. Sta. for 1959*, 48-51.

E516 Preston, A. P. (1960). **Effect of tree density in an exposed apple orchard.** *Rep. E. Malling Res. Sta. for 1959*, 52-6.

E517 Knight, R. L., and Keep, Elizabeth. (1960). **The genetics of suckering and tip rooting in the raspberry.** *Rep. E. Malling Res. Sta. for 1959*, 57-62.

E518 Trowell, G. F. (1960). **Weather conditions during 1959.** *Rep. E. Malling Res. Sta. for 1959*, 63-6.

E519 Rogers, W. S. (1960). **Fruit growing in Australia and New Zealand. Some impressions gained during a study tour in 1959.** *Rep. E. Malling Res. Sta. for 1959.* 118-21.

E520 Preston, A. P. (1960). **Pruning trials with dessert apples.** *Rep. E. Malling Res. Sta. for 1959.* 122-7.

E521 ——— (1960). **Pruning trials with Cox's Orange Pippin apple.** *J. hort. Sci.*, 35, 146-56.

E522 Beakbane, A. Beryl, and Labern, M. V. (1960). **The growth and cropping of five virus-tested clones of loganberry.** *Exp. Hort.*, **1**, 37-41.

E523 Knight, R. L., Briggs, J. B., and Keep, Elizabeth. (1960). **Genetics of resistance to *Amphorophora rubi* (Kalt.) in the raspberry. II. The genes A_2-A_7 from the American variety, Chief.** *Genet. Res., Camb.*, **1**, 319-31.

E524 Fulford, R. M. (1960). **The use of defoliating sprays for the control of biennial bearing in apple.** *J. hort. Sci.*, **35**, 202-13.

E526 Rogers, W. S., and Booth, G. A. (1960). **The roots of fruit trees.** *Sci. Hort.*, **14**, 27-34.

E533 Preston, A. P. (1960). **The shaping and pruning of fruit trees.** *J. R. hort. Soc.*, **85**, 397-412.

E535 Knight, R. L. (1960). **Notes on small fruit breeding at East Malling.** *Proc. 2nd Congr. Eucarpia, Cologne, July 1959*, p. 214 (abstr.).

II. STATISTICS AND RECORDS

Design and analysis

The designing of experiments has continued as before but with an increasing tendency to use new designs or even designs developed specially for the problems in hand, because it is now recognized that with modern methods there need be no serious difficulties of analysis whatever allocation of treatments to plots is decided upon. Indeed, almost the sole consideration nowadays is how to obtain the maximum efficiency for the important comparisons or estimates, bearing in mind the need to fit the experiment into a given piece of land. Limitations of shape and total area become ever more important as experiments are increasingly designed to occupy the space vacated by previous ones, and the present freedom of design is therefore especially welcome.

The first fully sequential experiment at this Station has been carried out. It concerned the breaking strengths of unions resulting from different budding techniques and would ordinarily have needed 64 trees, but in the event 40 sufficed.

Some 839 bodies of data were analysed for other sections; this is a very usual number though it is unusual in that the Elliott 401 electronic computor was employed for only three of them. The computor was, however, extensively used in the Section's own research work, as described below.

The programme for an electronic computor to enable analyses of variance to be worked out whatever the design has been completed and has proved useful.

Arrangements were made during the year for members of the East Malling Statistics Section to undertake the lectures at Wye College to post-graduate students on the statistical aspects of experimentation.

Record Office

Unfortunately the catalogue of completed trials was not quite finished by September 1960.

Historical studies have started again, chiefly on account of the new Trustee lands but partly to examine a few further documents that have been found relating to the old land.

The establishment of fixed survey posts in all fields has made possible the introduction of a system of grid references to specify precisely and clearly any point on the Station.

Statistical Research

Methods of experimental design and analysis

A note has been published (M57) on the interpretation of data from small experiments. Recognized methods, which will all lead to the same conclusions with large experiments, may each lead to a different result with small ones, and it is shown that each is appropriate to specific experimental situations.

A general class of design has been evolved that includes most of the designs in practical use and covers many of the situations brought about by mishaps, such as a plot receiving the wrong treatment.

A report is in the press on the designing of experiments in which some comparisons are more important than others ; particularly those in which one treatment, usually the control, has a special status, the differences that involve it being either more or less important than those that do not.

It is now realized that when blocks contain varying numbers of plots, as for example when some plots are missing as a result of mishaps, different results can be obtained according to the method of analysis adopted. These discrepancies have now been elucidated.

In studying the effect of one characteristic upon another, sudden changes in the relationship may arise on account of meteorological factors or of a new stage of development being reached. Methods of studying such regression problems are being evolved.

The uses of sequential methods in sampling and experimentation are being examined further, especially in relation to variety trials of strawberries.

A note has been published (M54) on the effect upon the standard errors of treatment means of missing data in a randomized block experiment.

A method that has been used in the Section for the last ten years for studying tree development has been described in its mathematical aspects (M52).

Statistical studies of biological problems

The electronic computor is now regarded as indispensable in biometrical studies. In the past, several months' labour might be needed to examine if a body of data supported or refuted an idea ;

now, once a suitable programme has been developed, it is easy to examine many bodies of data from a range of conditions. In this connexion a long-established record office is invaluable, and with the computor provides a new dimension in biometrical research.

An example is afforded by a study of sources of variation in apple trees using the technique referred to above (M52). The extensive computations called for are now carried out using the Elliott 401, and this has made possible the examination of data from trees on good and on poor land, on a range of varieties and rootstocks, and over periods that include changes in levels of fertilizer and that cover the trees coming into bearing.

During the year a report appeared (M51) on the choice of calibrating variates to improve the accuracy of experiments started on older trees of known history. Three bodies of data were used, though without electronic computation it would have required a major effort to have used even one.

The computor is of special importance in the use of multivariate methods of analysis, which would otherwise be nearly impracticable, yet these methods are now regarded at the Station as normal research tools ; for example, data from chemical analyses of leaves have in the past proved very difficult of interpretation, but during the past year by the use of multivariate methods clear results are beginning to appear. These methods are also being used to study the relations between crop, extension growth and various measures of growth derived from trunk girths, and to investigate how successive trunk girths are interrelated. An account has been published of the use made of these methods at the Station (M56), but already there have been considerable further developments.

Studies of a more fundamental kind on the measurement of fruit trees have been started and are likely to be intensified. The object is to find better means of measuring the growth characteristics of trees and to discern which are conducive to cropping.

The calibration studies on raspberries and black currants are nearly complete. A report has appeared (M55) on the measurement of extension growth in black currants.

The subsequent performances of trees planted with different ratios of tree weight to shoot length have been examined.

Field trials

The recording of the apple uniformity trial has continued ; in future records will be less detailed than was thought desirable in the early stages. Some further trees were lifted for cutting up and weighing. Examination of the data from the first nine years has begun.

In the trial on the restoration of soil uniformity the indicator trees on the long-term rotation were not all grubbed, though this had been intended at this stage. The remaining trees are being subjected to rigid pruning in the hope of reducing the considerable variation observed among them, thus improving sensitivity. After three years of such pruning and deblossoming the trees will be allowed to crop, and the detailed study of the residual effects of the previous plantation will be resumed.

PUBLICATIONS DURING THE YEAR

M51 PEARCE, S. C., and BROWN, A. H. F. (1960). **Improving fruit tree experiments by a preliminary study of the trees.** *J. hort. Sci.*, **35,** 56-65.

M52 ——— (1960). **A method of studying manner of growth.** *Biometrics,* **16,** 1-6.

M54 ——— (1959). **Loss of information resulting from loss of data.** *Nature, Lond.*, **184,** 1826.

M55 FREEMAN, G. H., and THOMPSON, J. A. (1960). **The assessment of wood growth on black currant bushes.** *Rep. E. Malling Res. Sta. for 1959,* 67-9.

M56 PEARCE, S. C., and HOLLAND, D. A. (1960). **Some applications of multivariate methods in botany.** *Appl. Statistics,* **9,** 1-7.

M57 SPRENT, P. (1960). **Analysis of small experiments.** *Nature, Lond.*, **187,** 437-8.

III. PLANT PHYSIOLOGY

The study of growth and form continues to occupy the Section, in the belief that only by understanding the factors which affect these attributes of the fruit tree will it ever be possible adequately to control its performance in the orchard. This study follows several lines of investigation, and although many of them interlock closely, in reporting on the work done in the year under review, it must be split up into somewhat arbitrary sections.

The distribution of dry weight in the tree

During each season leaves manufacture dry matter which is distributed to various parts of the tree ; the pattern of distribution, as much as the amount of dry matter produced, determines tree form and performance, and several small-scale experiments over the last few years have been conducted to analyse this pattern. During this last year the emphasis has been on the assimilation and preparation for publication of the results of these experiments, and in continuing existing trials, rather than on starting many new ones.

Critical analysis of the experiment mentioned last year on *leaf and root efficiency* showed that removing half the leaves led to increased efficiency of the remainder, but results will not be published in full until confirmed. Final consideration of the results of the *growth of rootstocks under a range of conditions* led to a paper in which a distinction was drawn between treatments which alter the pattern of distribution of increment and those which alter the amount of increment without changing its distribution. This concept will help in interpreting many results, notably the ' stock-on-stock ' experiment which is still under analysis. The experiment concerned with *the importance of stem length in relation to tree growth* has passed the critical first year with few losses following the removal of the nurse roots.

The attempt made last year to estimate the *Net Assimilation Rates* (*NAR*) *of young apple trees* over fortnightly intervals was successful although the results were rather difficult to interpret. For example, over the period 8th-22nd July, the NAR for Laxton's Superb on the invigorating stock M.XXV was higher than that of the same variety on the dwarfing 3431, with M.VII intermediate. On the other hand in the preceding fortnight the order was reversed ; this may have been due to the removal of fruitlets from the scion on 3431 three weeks earlier, none being borne on the other stocks. This is an important point to confirm. In another experiment in late August NAR's were lower and more variable.

The main source of error in this type of work is the estimation of dry weight at the start of an experimental period, and to increase the accuracy of this estimate the Statistics Section has collaborated in extending the multiple regression techniques employed in earlier investigations here. Final conclusions must await further work, but interim results are promising.

Trials being continued include one on *the effect of stock pruning on scion growth* ; scions of three plum varieties were grafted this spring onto stock stems cut back to three different levels. 'Take' was somewhat variable, but growth of the successes was very vigorous ; first samples are due this winter. Another experiment was aimed at *discriminating between ' true ' and ' false ' dwarfing cherry rootstocks* by growing shoots and roots of certain John Innes seedlings on vigorous nurse trees ; all of the seedlings tested seemed to be severely ' shoot-limited ', so that as rootstocks they may not be so dwarfing as the appearance of the seedlings might suggest. Root-grafts were spoiled by waterlogging, but a greatly improved technique has been worked out this year, and will be used next year in a repeat study.

A new experiment was planted last winter on *the effect of time of pruning* on the increment in dry weight and its distribution, the aim being to find an overall pruning hypothesis to reconcile the ' dwarfing ' effect of summer pruning with the ' invigorating ' effect of winter pruning.

An attempt is being made to assess the relative *efficiency of leaves* on unbranched extension shoots and on lateral branches. Established Crab C ' treelets ' carrying a dozen vigorous shoots were either left untreated, or induced to branch during the current year by decapitation or defoliation in the tip region. Leaf areas and shoot weights will be compared ; there was no effect of treatment on girth increment of the trunk.

Last year mention was made of the reduced CO_2 uptake by leaves damaged by fruit tree red spider mites. This year the effect of such damage on potted Brompton cuttings was assessed by growth analysis. The growth of plants inoculated early in June was seriously reduced, and the distribution of increment affected ; the root system of the infested plant was only half the weight of the controls, although the leaf surface was reduced very little. The assistance of the Entomology Section in supplying the mites is gratefully acknowledged.

Growth and form in terms other than dry weight

In the experiment on *the effect of extreme pruning regimes and of deblossoming on growth* the trees on M.XVI are now too large for detailed records of the whole tree to be practicable ; this year three sample branches per tree were selected for such records as extension growth and numbers of flower trusses, and it is hoped to relate the data obtained to the whole tree through the basal girths of all main branches.

The residual effects of five years' *hand thinning of Sunset apples*, in collaboration with the Pomology Section, were followed this year by means of counts and measurements of fruitlets and shoots ; a large effect on shoot growth of the earliest thinning treatments persisted, but final size of fruit was unaffected. A curious result of these same treatments was the retention of the petals until the fruitlets were quite large.

Detailed studies of *foliage development* were continued on the branches selected last year, but work was extended to tackle the problem of estimating the leaf surface on large trees. The essence of the matter is to find a sampling method which deals adequately with the variability of the material and yet is sufficiently quick for truly comparative data to be obtained. The components measured this year, which it is hoped will provide a reasonable estimate speedily, were the basal girths of the main branches, counts of ' growth units ' (the outgrowth of a last year's bud, which might, for instance, be a flowering spur, a vegetative cluster or an extension shoot) on some of these branches, counts of leaves on at least 100 growth units on one branch, and leaf areas on growth units on sample shoots. Analysis of the information is in hand.

The demonstration given at Montreal last year on *the experimental modification of axillary branch form* has been written up, and will shortly be published in an American journal. One of the points which arose from that investigation has been clarified by an experiment this year. By decapitating the main shoot at a critical level within the terminal cluster of unexpanded leaves, the basal pair of primordia on the lateral meristem may be induced to develop into crescentic foliar organs instead of the usual bud-scales ; this level has been raised or lowered respectively by the presence or absence of a subtending leaf, suggesting that a leaf slows up the early development of the meristem in its axil.

Further experiments on controlling *crotch angles* in cherries and plums, other than Victoria, have been disappointing, particularly an abortive attempt to obtain wide angled F12/1 staddles.

Spray damage investigations

The work this year might well appear under both of the previous headings, since in one experiment the effect of 2% lime-sulphur on the growth of M.IV rootstocks was assessed by growth analysis, and in another the importance of the spur leaves, often scorched by lime-sulphur sprays, was evaluated.

Early applications of lime-sulphur to the rootstocks caused a significant decrease in growth rate, but additional applications resulted in no further reduction, and after about six weeks the sprayed plants had nearly compensated for their early check, their weights almost equalling those of the unsprayed controls.

In the other experiment, bearing trees of five varieties were sprayed with $2\frac{1}{2}$% lime-sulphur at green-cluster and pink bud, and the effect on fruit set and tree growth compared with the removal of all leaves at the same times—simulating extreme spray damage. In this season none of the sprayed trees showed any damage (not even the sulphur-shy Stirling Castles), but in the varieties Cox's Orange Pippin and Worcester Pearmain leaf removal greatly increased June drop, with the result that the final crop was less than half that of the untreated or the sprayed trees.

Carbohydrate resources

Attempts to discover conditions under which reserve materials are most important to the orchard tree have been continued this year by interrupting the translocation of newly formed carbohydrates from the leaves. This has been done by removing rings of bark from the branches of Y-shaped trees (described last year) at a time shortly after bud-break when reserves are likely to be at a minimum and critical to the tree's economy.

Chemical analyses of samples taken during the two-month period following bud-break in March indicate that ringing accentuates the depletion of carbohydrate in the growing shoot above the ring, but delays the utilization of reserves from other parts of the tree. Measurements of the trunk diameter increments of the same trees suggest that stem thickening utilizes reserve materials until late July, after which it becomes dependent on products of photosynthesis from the current leafy growth.

The present experiments are with non-cropping trees and have yielded further samples which await analysis, but other Y-shaped trees are being prepared to assess the combined effects of cropping and growth on the depletion and replenishment of carbohydrate resources. Trees of this shape are proving

to be satisfactory experimentally and are included in continued tests of methods for taking successive small samples from the same trees without adverse effects.

It was hoped that *direct measurements of CO_2 uptake* would assist in many aspects of the Section's work, especially those under the previous two headings, but although it has been shown this year that the apparatus itself is sufficiently accurate for the work in hand, the behaviour of the leaf has been found to be erratic, wide fluctuations of activity sometimes occurring even under constant environmental conditions.

Natural formative and growth controlling substances

A new line of work was begun this year : an investigation of *the morphogenetic role of the root* apart from its activity as the supplier of water and nutrient salts.

Growing rootstock material in sand culture made it possible to remove and replant the root system by submerging the container in a bucket of culture solution. Little harm resulted from this operation, but cutting off the tips of the roots (as far as was practicable with the ' fuzz ' of roots formed on these rootstock shoots) markedly reduced the rate of development of leaves at the stem tip, and the size of those leaves which grew out after treatment. How far reduced water uptake was the cause was investigated by measuring water loss from plants after various treatments, but unequivocal results were not obtained in this first season's work. Most of the plants were grown in polythene containers of various sizes, and growth was very satisfactory so long as completely free drainage was provided.

Mist culture is the obvious system for this kind of work, but it has been difficult to make this trouble-free and safe from failure. This year many advances have been made towards a reliable system in which a limited number of plants can be grown, rather than attempting the large-scale layout tried a few years ago with near, but not adequate, success.

In some subsidiary experiments in sand culture, apple and plum rootstocks were grown in the presence of various dosages of dried apple and plum roots, and of phloridzin. The aim was to simulate the deleterious effect on growth of root residues of the same species as the test plant, and to ascertain whether phloridzin, present in apple roots and reported to be important in the ' replant problem ', would reduce growth of the apple under these conditions, but not of the plum. In the event no treatment had any effect whatever ; confirmation of this result in other media will be sought before wide conclusions are drawn.

Work on *the response of coleoptile sections to plant extracts* continued, particularly in connexion with work undertaken at the A.R.C. Unit of Growth Substances and Systemic Fungicides at Wye College on the purification and identification of the inhibitor of cell extension extracted from Myrobalan shoots. The preparation of crude inhibitor was done here, and after each stage of purification at Wye the various fractions were returned for bioassay. Grateful acknowledgement is here made to Professor R. L. Wain and Dr. C. H. Fawcett for their collaboration.

Several *apple root extracts* were assayed in connexion with the new line of work mentioned above, and some extracts of leaves and internodes examined relating to the survey of natural growth promoters and inhibitors carried out some years ago. Among the inhibitors found in apple root and shoot extracts was one which had an effect on coleoptile sections different from the rest ; this has now been identified as the glucoside *phloridzin*, and its characteristics in this assay method have been described for publication elsewhere, while a paper concerned with its secondary effects in the coleoptile straight growth test appears in this report (p. 72).

Publications during the year

F107 Hatcher, E. S. J. (1959). **The propagation of rootstocks from stem cuttings.** *Ann. appl. Biol.*, **47,** 635-9.

F109 Priestley, C. A. (1960). **Seasonal changes in the carbohydrate resources of some six-year-old apple trees.** *Rep. E. Malling Res. Sta. for 1959*, 70-7.

F110 Maggs, D. H. (1960). **The efficient fruit tree.** *Rep. E. Malling Res. Sta. for 1959*, 128-31.

F111 Barlow, H. W. B. (1960). **Root/Shoot relationships in fruit trees.** *Sci. Hort.*, **14,** 35-41.

F112 Maggs, D. H. (1960). **The effect of number of shoots on the quantity and distribution of increment in young apple-trees.** *Ann. Bot., Lond., N.S.*, **24,** 345-55.

F113 Barlow, H. W. B., and Hancock, C. R. (1960). **The experimental modification of branch form in an apple rootstock.** *Bot. Gaz.*, **121,** 208-15.

F114 ———, and ——— (1960). **Short-term fluctuations in leaf and internode growth in the apple rootstock Crab C.** *New Phytol.*, **59,** 227-37.

IV. BIOCHEMISTRY

Metabolism of the apple tree

Some observations of the metabolism of the sugar alcohol, sorbitol, were reported last year. Further work has indicated no direct relationship between the amount of sorbitol in apple leaves and some other constituents, notably starch. In leaves used to demonstrate starch formation from sorbitol, the quantity of starch produced bore no simple relation to the uptake of sorbitol, nor was there an increase in the quantity of free sugars.

Although sorbitol is of general occurrence in the apple tree, its concentration in the fruit is much less than in other parts of the tree. A crude enzyme preparation that was able to produce a sugar from sorbitol was obtained from the fruit cortex. Nothing is known as yet about the distribution (if any) of the enzyme in other parts of the tree, but this is the first indication that the tree might be able to use at least some of its large store of sorbitol for growth processes.

A general examination of the composition of one-year-old dormant shoots of Cox's Orange Pippin on M.XIII has been completed. The bark and the wood were examined separately, and standard methods were used to separate the lipids, phenolic compounds, organic acids, sugars and soluble nitrogen compounds. The structural material, isolated here as the alcohol insoluble fraction, was found to be typical of a hardwood tree in that the hemicelluloses yielded a considerable quantity of mannose on hydrolysis, in addition to xylose, arabinose, glucose, and galactose. A sample of lignin (from the wood) when degraded produced vanillin, syringaldehyde, and *p*-hydroxybenzaldehyde. The bark contained about twice as much pectin and associated polysaccharides as the wood, whereas the wood contained much more starch than the bark.

For any future detailed work on the structural polysaccharides it was encouraging to find that holocellulose could be prepared from either wood or bark without loss of polysaccharide if delignification was achieved using sodium chlorite and acetic acid.

Host-parasite relationships

Further work on the mechanism of inhibition of *Venturia* spp. by different polyphenols has led to a study of the acid metabolism of the fungus in relation to sporulation. Intense inhibition of sporulation was obtained when the fungus was grown in culture in the presence of malonate, arsenite, trans-aconitate, and fluoracetate, although there was apparently normal mycelial growth except when fluoroacetate was used. The latter compound, unless present in very low concentrations, checked mycelial growth. All these compounds are known to inhibit particular stages in the acid metabolism of organisms, and analysis of the culture medium at the end of the experiment has shown that in one case (arsenite inhibition) the block in acid metabolism is at the expected place. In the other cases, analysis is hampered by the nature of the culture medium itself, but attempts are being made to overcome this. This type of inhibition of sporulation is being compared with that due to *o*-coumaric acid in an attempt to elucidate the mechanism of the latter.

Biochemistry of fruits

The work reported under this heading was carried out in collaboration with the Ditton Laboratory and the Fruit Storage Investigations team (p. 38).

Analysis of the samples of Cox's Orange Pippin apples collected during the 1959 growing season from trees grown under two different cultural treatments has continued. All trees received phosphate and potash but differed in that one set was cultivated and received nitrogen (NPK), whereas the other set received no nitrogen and was grassed down in 1953 (PKS). Samples were taken at intervals during growth on the tree from petal-fall to maturity. At each sampling date, one sample (the initial) was analysed immediately while others were stored at 12° C for various periods (cf. Rep. E. Malling Res. Sta. for 1959, p. 17). The peel and pulp of all the initial samples have now been analysed.

In both peel and pulp the fluctuations in malic acid are similar with both cultural treatments, but the concentration of the acid is higher in fruit from the NPK trees than from the PKS trees. In the pulp, the concentration of quinic acid is similar in both cultural treatments throughout the season, being high in young fruits and falling to a very low value at maturity. In the peel there is considerably more quinic acid in fruit from the NPK trees than from the PKS trees at the beginning of the season, but from mid-July onwards the quinic acid concentration follows the same course in both treatments. At maturity there is about twice as much quinic acid in the peel as in the pulp and the fall in concentration of this acid takes place much later in peel than in pulp.

The respiration of the whole fruit and of discs of peel taken from it is slightly higher in the case of the NPK treatment than in the PKS treatment. However, the response (carbon dioxide output) of the peel to addition of malic acid is considerably higher throughout the season with the PKS treatment than with the NPK treatment. This difference is even more striking at the extreme end of the storage life of the fruit when that from treatment NPK shows little response to the addition of malic acid, whereas the response of peel of fruit from treatment PKS is still fairly vigorous.

The significance of these differences in behaviour will only be apparent when the samples in store at 12° C have been fully analysed.

Publication during the year

Kiio Flood, A. E., Hulme, A. C., and Wooltorton, L. S. C. (1960). **The organic acid metabolism of Cox's Orange Pippin apples. I.** *J. exp. Bot.*, **11**, 316-34.

V. FRUIT NUTRITION

Some of the aspects in this report are developments of work originating in the Plant Analysis Section, which was amalgamated with this Section on 1st October 1959. The progress described under the heading 'Uptake of magnesium from foliar sprays' represents a continuation of work on that subject previously reported by the Plant Protective Chemistry Section.

Soil moisture supply

The wet summer contrasted strikingly with the 1959 season. After the soil moisture deficit reached a maximum of 4 in. during the first week of July, rainfall gradually replenished the soil reserves and field capacity was reached during September. Throughout the season, tensiometers, even under trees in grass, showed relatively low soil moisture stress conditions. Thus the season afforded an opportunity to observe the residual effects of the previous year's drought.

Tree fruits.—The separate effects of supplementary water and a high rate of applied nitrogen on the growth and cropping of the Laxton's Fortune apple trees on Plot L7 were again similar, but together these treatments now appear to be giving a completely additive effect on growth and only a partially additive effect on yield. Compared with unwatered trees receiving a low rate of nitrogen, water and high nitrogen together increased the crop picked this season by 95% whilst the separate treatments each gave an increase of about 60%.

The proportion of the picked crop grading between $2\frac{1}{4}$ and 3 in. was low (42%) on the watered plots at both nitrogen levels compared with the unwatered plots (57% from trees receiving high nitrogen and 48% from those with low nitrogen); the remainder of the picked crop was less than $2\frac{1}{4}$ in. in diameter. Wastage from all treatments was high (20%), mainly because of hail damage.

Considerable leaching of soil nitrogen probably occurred, particularly where the heavy rainfall was supplemented by 11 in. of water, applied on 12 ft diameter basins to prevent the soil moisture tension at 1 ft depth from exceeding 10 cm Hg, and fruit size may have been affected by reduced nitrogen availability to the large number of developing fruitlets. Nitrogen determinations are being made on leaves sampled at monthly intervals throughout the season to ascertain to what extent nitrogen deficiency may have accounted for the large proportion of small fruit, particularly on the irrigated trees.

The influence of the different treatments on early and preharvest drop of fruit is also being investigated.

The Laxton's Superb apple trees in the same plantation cropped heavily, the yield of marketable fruit grading between $2\frac{1}{4}$ and 3 in. being over 900 bushels per acre from the trees under each water treatment, compared with 600 bushels from the unwatered control trees. This large difference accurately reflects the difference in tree size. The unwatered trees in this trial appeared to be suffering from the previous season's drought, judging from their very limited shoot growth and relatively sparse foliage.

The water treatments applied to the Cox's Orange Pippin trees in the collaborative trial at Luddington Experimental Horticulture Station are stimulating growth excessively. A late spring frost again caused light crops with the result that very vigorous growth has been maintained. The storage quality of the fruit is being examined; losses from breakdown and bitter pit during storage of the 1959 crop were greater from the watered than from the unwatered trees.

Small fruits.—Malling Jewel and Malling Exploit raspberries yielded respectively 11% and 17% more from watered than from unwatered plots. These increases were smaller than in previous years but in terms of crop increase per inch of applied water the response was as great as before. The mulched raspberries cropped as heavily (6 tons/acre) as those in the watered plots. The ripening of the fruit of both varieties on the watered plots was delayed by about 8 10 days compared with the unwatered and the mulched plots.

The two water treatments in this trial continued to show similar effects on growth and cropping, indicating that, for raspberries on this type of soil (Plot E35), frequent light applications (at a soil moisture tension of 20 cm Hg) have no advantage over less frequent heavier applications (at 50 cm Hg). The former treatment will therefore be replaced by a single water application prior to picking, with a view to studying the effectiveness of this treatment in maintaining growth and berry swelling.

Irrigated Amos Black black currants considerably outyielded the unwatered bushes, reflecting the serious effect of the 1959 drought on growth.

Previously, treatment effects have been assessed on unpruned bushes only, but this year a comparison with orthodox pruning has been superimposed on the trial. The immediate effect of pruning, as

was to be expected, was to reduce the crop by 50% on both watered and unwatered plots. There was again no marked benefit from the high nitrogen treatment but the yield of both pruned and unpruned bushes was 60% higher from the irrigated than from the unwatered bushes. Thus at one extreme the watered unpruned bushes yielded 5·13 tons/acre while at the other the unwatered pruned bushes yielded only 1·70 tons/acre.

Mineral nutrition

Long-term manurial trials

In the manurial trial on Plot C2, the trees of Cox's Orange Pippin on M.XII again cropped heavily, and the average fruit size was greater than usual. This year the crop was rather heavier in the plots grassed down in 1953 than in those under cultivation with autumn weeds, and there was a marked response to the nitrogen applications on both grass and cultivated plots. Even in this wet season, the trees in the sward plots to which no nitrogen is applied, and in which clover is therefore abundant, had noticeably paler foliage than those in the grass plots receiving nitrogen.

The pear manurial trial started at Efford Experimental Horticulture Station last year in collaboration with Long Ashton has suffered a setback. A widespread outbreak of silver leaf disease, mainly in the variety Conference, has necessitated the removal of all the experimental trees of that variety; these will be replaced with maiden trees. The trees of the other experimental variety, Doyenné du Comice, appear to be unaffected, apart from one instance, and the treatments will be continued.

Nitrogen

Treatments have started, on dessert apples in grass at Efford Experimental Horticulture Station, in the trial devoted to the study of the effects of times of application of three different kinds of nitrogenous fertilizer.

Studies of the seasonal trends of ammonium and nitrate nitrogen in orchard soils have revealed fairly consistent treatment effects over two seasons in the apple manurial trial (Plot C2). Thus, on plots receiving 8 cwt/acre of 'Nitro-chalk' each year, the soil nitrate levels were markedly lower in grass than in cultivation; where no nitrogen was applied, the levels remained low throughout the season even in cultivated plots. In 1960 the nitrate levels in the top 2 ft of the cultivated plots receiving 'Nitro-chalk' in February and April reached their highest values by the end of June and then, with the onset of wet weather, fell gradually to very low values by October; this contrasts sharply with the dry season of 1959, when high soil nitrate levels were maintained in these plots until October.

Differential nitrogen treatments were applied to the trees of Cox's Orange Pippin on M.VII which had been planted in 40-gal. drums of sand in 1959. The culture technique was substantially the same as in the previous season, the nutrient solution draining to the bottom of each drum being pumped off daily and re-applied to the surface of the sand, but the volume of solution circulating was maintained by additions of water only, and it was replaced fortnightly with fresh solution. Nitrogen was omitted entirely from the nutrient solution supplied to half the trees. This made little difference to their growth in the early part of the season, but by August the trees lacking nitrogen were less vigorous and their leaves were smaller, paler green and beginning to senesce. Trees receiving nitrogen made extremely vigorous and healthy growth.

In a new strawberry manurial trial in collaboration with the Pomology Section, treatments including farmyard manure, inorganic nitrogen fertilizers, and heavy dressings of straw have been applied to establish a wide range of soil nitrogen levels. Preliminary determinations of soil nitrate have indicated that four fairly distinct regimes have been established. The regular sampling of leaves in this trial should provide information on nutrient status in relation to cropping.

The interaction of nitrogen treatments with soil moisture supply, and the response to nitrogen applications in the long-term manurial trial on apples, have been referred to above.

Magnesium

The trial of the effects of pre- and post-blossom spray applications of Epsom salt on growth and cropping of magnesium-deficient dwarf pyramid Edward VII on M.VII was continued for a second year. Although pre-blossom sprays prevented the appearance of early-season deficiency symptoms on fruiting spur leaves, they did not reduce the severity of symptoms developing later on extension shoots. Such symptoms did not develop to any appreciable extent on trees receiving five post-blossom spray applications of 2% Epsom salt or of 0·83% magnesium chloride (a solution of equivalent magnesium content to 1% Epsom salt), but three applications of the latter were less effective. In a similar experiment on Crab C rootstock sprayed three times, 0·83% magnesium chloride was again found to be as effective as 2% Epsom salt in preventing symptom development.

In view of the large increase in crop of dwarf pyramid trees obtained over five years by five post-blossom spray applications of Epsom salt each year (U20,U23), a similar trial was started in 1960 with mature trees under commercial conditions ; three varieties are involved, on rootstocks M.II and M.VII. Severe symptoms of magnesium deficiency occurred on all trees worked on M.VII other than those sprayed with Epsom salt, whereas practically no symptoms occurred on those worked on M.II. It is hoped that the trial will show whether the crop of the latter can be improved by spraying with Epsom salt even in the absence of foliar symptoms of magnesium deficiency.

The Epsom salt spray trial on a stoolbed of M.IV rootstocks was discontinued in 1960, and the residual effects of three and nine spray applications of Epsom salt in each of the past seven years are being assessed. The severity of foliar symptoms in 1960 reflected the previous years' treatments. In the trial with MM.102 rootstocks there was still little response to soil applications of Epsom salt, possibly owing to the applied magnesium not having yet reached the absorbing root zone.

A pot experiment carried out in collaboration with the Plant Protective Chemistry Section (p. 81) showed that 2% Epsom salt foliar sprays reduced the incidence of mildew on MM.102 rootstocks. The greatest control was given, however, by a single application one day before the artificial mildew inoculation, due apparently to the deposit of Epsom salt remaining on the leaf surface. Further work is necessary to elucidate the effect of magnesium nutrition on the susceptibility of the plant to mildew.

In orchards, magnesium deficiency is frequently associated with high concentrations of ' available ' potassium in the soil and in these cases it is often very difficult to cure the trouble by applying magnesium salts to the soil. To eliminate the complicating factors in the soil affecting availability of these nutrients, and to study the interactions of potassium and magnesium supply to the roots, M.VII rootstocks have been grown in sand with nutrient solutions supplying adequate or low concentrations of magnesium and high, adequate or low potassium. Symptoms of magnesium deficiency developed first on plants with a high ratio of potassium to magnesium in their nutrient solution, irrespective of magnesium concentration itself. Potassium deficiency symptoms, however, appeared only on plants with a very low supply of potassium. Dry weights and chemical analyses of samples obtained at four times in the season will show how uptake and distribution in the plant of these and other elements have been affected.

A new trial at Luddington Experimental Horticulture Station, mentioned below, will afford an opportunity of observing responses of apple trees in the field to varying levels of applied potash and magnesium.

Uptake of magnesium from foliar sprays

Investigations on the uptake of magnesium from foliar sprays have continued. It was earlier shown (U26) that different salts behaved differently, and this was attributed to the fact that deposits from some salts remain longer in solution on the leaf surface or re-absorb moisture after drying. Recent work has confirmed that uptake is initiated only by a wet deposit, but it has also shown that magnesium is not always taken up in appreciable quantity even when the leaves are exposed to a wet deposit for an hour or more ; it appears, therefore, that uptake is also influenced by some factor associated with the leaf, and in the past year attention has been concentrated on the condition of the leaf.

The trees of Edward VII and Crab C mentioned earlier have provided material for a detailed study of the nutritional status of leaves showing magnesium deficiency symptoms, and for an assessment of the effects of foliar sprays of magnesium sulphate and chloride on mineral composition.

Studies on the mineral composition of apple plants

A paper (V6) was published on seasonal changes in the uptake and distribution of mineral elements in apple trees ; this was prepared by the Plant Analysis Section last year.

A collaborative trial was started at Luddington Experimental Horticulture Station with the object of determining at intervals the mineral composition of Cox trees grown on M.VII under various nutritional conditions. The trees were planted in December on sandy soil of very low potash and magnesium status, and have received the first annual applications of the treatments consisting of 4 cwt/acre sulphate of potash and 10 cwt/acre Epsom salt, separately and together, with untreated control plots. Trees will be lifted at intervals from about 1965 onwards for determination of their total content of the major elements ; this information, together with estimates of the nutrients removed in prunings and fruit, should enable the uptake over periods of years to be calculated.

The assessment of the total amount of any element in a tree presents a major problem in sampling ; the taking of representative sections at intervals of a few inches along branches, trunk and roots is a laborious procedure. An alternative possibility examined in collaboration with the staff of Alice Holt

Forest Research Station is to use a machine to reduce whole apple trees to chips which can easily be sampled. The results of this study await analysis.

Routine Analysis Unit

The routine determination of mineral elements in plant material is carried out as a general service for the Station ; although the greatest demand arises from the research programme of the Fruit Nutrition Section itself, analyses have also been done for most of the other Sections.

Some 3,000 plant samples have been analysed by microchemical methods during the year, mostly for the major elements nitrogen, phosphorus, potassium, calcium, and magnesium, but including some determinations of iron and manganese. Nutrient solutions and farmyard manure have also been analysed for content of major elements.

A microdiffusion method has been used for the determination of nitrate and ammonium nitrogen in some 800 soil samples in connexion with the studies mentioned above on the seasonal trends of ' available ' nitrogen in orchard soils, and nitrate nitrogen was also determined on root samples. A few soil samples were analysed for total nitrogen.

Further testing of chemical methods for the determination of zinc and copper has ensured that the analysis of plant material for these elements can be undertaken.

The summer leaf sampling programme included further visits to some of the orchards in south-east England from which samples were taken in the three previous seasons for a survey, the results of which are being prepared for publication. Samples were taken from the apple manurial trial (Plot C2) for further study of the relationships between the mineral composition of leaves in different positions.

Soil management trials

In the soil management trial on Plot C11, most of the Laxton's Superb trees were in an ' on ' year and carried a very heavy crop ; many of the branches had to be supported.

In the pilot trial on cherries, a further pair of plots was sown with a grass and clover mixture. The crop was recorded for the first time, six years from planting, but was still small.

Soil variation at East Malling

The efficient siting and planning of field trials at the Station demand a detailed knowledge of the land, and Furneaux's soil surveys of the Research Station and the Trust land have now been supplemented by a study of soil pH over the whole area (p. 77). Collaborative studies with the Statistics Section of the history of the Trust land are progressing.

Progress in the trial on the restoration of uniformity of old orchard land is reported by the Statistics Section (p. 14).

The possibility of reducing one source of soil variation, by introducing a method of spreading fertilizers more uniformly than at present, is under discussion with the staff of the National Institute of Agricultural Engineering. On another aspect, collaboration with the N.I.A.E. offers the hope of economizing in the use of experimental land by the insertion of mechanical barriers in the soil in place of guard trees for some types of field trial.

PUBLICATIONS DURING THE YEAR

U20 GREENHAM, D. W. P., and WHITE, G. C. (1959). **The control of magnesium deficiency in dwarf pyramid apples.** *J. hort. Sci.*, **34**, 238-47.

U22 PHILCOX, H. J. (1960). **The design and use of an improved rotating disk electrode for spectrographic analysis of solutions.** *Spectrochim. Acta*, **16**, 384-9.

U23 WHITE, G. C. (1959). **Epsom-salt sprays raise output.** *Grower*, **52**, 907-9.

U24 GOODE, J. E., and HYRYCZ, K. J. (1960). **The soil moisture tensiometer: its practical value for field use in fruit crops and its construction.** *Rep. E. Malling Res. Sta. for 1959*, 78-84.

U25 ALLEN, M. (1960). **The uptake of metallic ions by leaves of apple trees. I. The magnesium content of untreated leaves.** *J. hort. Sci.*, **35**, 118-26.

U26 ——— (1960). **The uptake of metallic ions by leaves of apple trees. II. The influence of certain anions on uptake from magnesium salts.** *J. hort. Sci.*, **35**, 127-35.

V6 MASON, A. C., and WHITFIELD, A. B. (1960). **Seasonal changes in the uptake and distribution of mineral elements in apple trees.** *J. hort. Sci.*, **35**, 34-55.

VI. PLANT PATHOLOGY

BACTERIAL DISEASES

Fire-blight of pear *(Erwinia amylovora)*

Studies on the morphology, physiology and biochemical activities of the fire-blight pathogen have been extended to include a wider range of isolates. The dissimilation of 36 different carbon compounds including sugars, alcohols and organic acids has been tested by conventional methods and by a modified auxanographic technique. All cultures required nicotinic acid for growth, but within large populations there was evidence of non-exacting mutants.

Bacterial canker of stone-fruits *(Pseudomonas mors-prunorum)*

The first phase of the spray trial against cherry bacterial canker was completed and four new treatments, including unsprayed controls, were superimposed on the old. The spray schedules all greatly reduced infection, but freshly made Bordeaux mixture gave better control than copper oxychloride diluted to a lower copper content to lessen spray damage risks. Counts of *Ps. mors-prunorum* on the leaf surfaces confirmed the superiority of Bordeaux mixture as a bactericide. Spring sprays reduced the numbers of bacteria on the leaf surface but the numbers increased during the summer, reaching a final level at about one tenth of the numbers on the unsprayed trees. Autumn sprays substantially reduced the leaf surface populations but the precise numbers could not be determined because of the carry-over of copper or other toxic substances from the leaf washings into the isolation plates.

A search was begun in collaboration with the Pomology Section for cherry rootstocks immune or very highly resistant to the disease. About 1,200 mazzard seedlings were inoculated in the autumn of 1959. Approximately two-thirds of these were cankered by June and were removed, the remainder being left *in situ* for further inoculation.

In a joint trial with the Pomology Section 67 clones of seedlings of St. Julien of Orleans plums were tested for susceptibility to bacterial canker. Preliminary results suggest that 24 clones were highly resistant or immune.

Isolates of *Ps. mors-prunorum* from surfaces of cherry leaves differed in virulence but all were pathogenic. Streptomycin-resistant variants, isolated in the laboratory, did not differ significantly in virulence from the original parent strains, indicating that resistance to streptomycin and virulence are unrelated. Surveys of leaf populations of *Ps. mors-prunorum* on unsprayed trees and trees sprayed for several years with streptomycin have so far provided no evidence of resistance to streptomycin in the field.

The multiplication of *Ps. mors-prunorum* within cherry and apple leaves was studied after infecting the leaves through the stomata. In apple leaves no growth was detected, but in cherry leaves growth was related to the concentration of inoculum and age of the leaves. Symptoms were produced with both high and low concentrations of bacteria on young leaves, but no symptoms were observed on mature leaves with low concentrations although there was growth of the pathogen.

An investigation of the disease cycle on plum was begun in 1959. Attempts to infect plums through leaf scars or lenticels were unsuccessful. Cankers comparable in size to those observed in the field were induced by introducing the pathogen into the bark or wood through wounds at different times between October and April. The tissues were most susceptible from November to January and the longest cankers resulted from the December inoculations.

Large numbers of the pathogen were present in rain-water draining from trees during summer, but in the winter months, when plums were most susceptible, the numbers were too small to be detected by conventional methods. The numbers from cherry trees increased markedly at bud-burst, but from plum trees large ' catches ' of the pathogen were not obtained until July.

Bacteriophages

Plaque size and phage counts were related to the age and density of the bacterial culture used for propagation. Plaque size decreased above a density of 10^8/ml and cultures older than 30 hours reduced the count. Variations in pH, agar and constitution of the propagating medium effected no improvement.

Phages have now been successfully stored over chloroform at 0° C for periods of 20 months without loss of titre.

A further 30 phages active against *Ps. mors-prunorum* and *Ps. syringae* have now been isolated, making a total of 45 now in stock. Phages for *Ps. viridilivida, Ps. angulata,* and *Ps. pisi* have also been isolated from soils and farmyard manure.

Twelve *Ps. mors-prunorum* phages have been tested against 40 plant pathogenic *Pseudomonas* spp. Half the bacterial species were completely resistant and the remainder reacted with from 1 to 8 of the phages. Phages themselves varied considerably in host range, but none was specific for *Ps. mors-prunorum*. Phages active at high titre against both *Ps. mors-prunorum* and *Ps. syringae* would differentiate between the species when used at low concentrations.

FUNGAL DISEASES

Apple and pear scab (*Venturia* spp.)

Host parasite relationships

The collection and storage of single spore isolates of *V. inaequalis* and *V. pirina* has continued. Existing clones have shown no loss of virulence after prolonged storage under paraffin oil. Reisolation of these clones from artificially infected Cox leaves is in progress.

Using the paper-cylinder technique, several standard inhibitors of the Krebs cycle including sodium malonate were found to inhibit sporulation, and one of them, fluoroacetate, also inhibited mycelial growth except at very low concentrations. The results suggest that blocking the acid metabolism in the Krebs cycle and/or other acid pools causes a marked inhibition of sporulation.

In collaboration with the Biochemistry Section, exogenous acid profiles in large-scale liquid cultures have been examined in the presence of standard inhibitors and *o*-coumaric acid. Sodium arsenate increased the concentrations of keto-acids in the medium, but this was not observed with *o*-coumaric acid. Nevertheless there was some indication of an altered profile with the latter and this is being further investigated.

Infection of glasshouse plants of Cox's Orange Pippin with clone E1 of *V. inaequalis* was greatly increased by injection of sodium malonate. This result was unexpected and indicated a different effect on host parasite relationships from *o*-coumaric acid which has been shown previously to inhibit infection when injected.

Attempts are being made to increase the penetration of *o*-coumaric acid into apple leaves. The methyl, ethyl, propyl, butyl and heptyl esters, prepared by the Plant Protective Chemistry Section, were tested as spray applications 24 hours after infection of Cox and Worcester shoots with Clone E1. Results are incomplete, but there is a strong indication that the propyl ester was more active than the acid under the test conditions used.

Epidemiological studies

Studies of spore dispersal and infection ('Mills') periods have been continued in collaboration with the Plant Pathology Laboratory, Harpenden. Nine infection periods were recorded between the end of March and mid-June. The disease was given an early start by a discharge of ascospores during a prolonged wet period when the first leaves were emerging.

In the Bramley orchard where the spore trap was sited, no ascospores were detected after mid-May despite frequent rain during the summer. Although weather conditions during 1960 favoured ascospore liberation, the total inoculum trapped in this orchard was substantially lower than in the two previous years. This may be related to the virtual absence of late-season infection during 1959.

Progress has been made with experiments to determine the effects of various fungicides on perithecial formation and ascospore production. Leaves were treated with fungicides in the autumn and spore production estimated in small-scale wind tunnels the following spring. Of several fungicides screened, only 0·1% PMC completely suppressed spore production. Captan, cyprex, lime-sulphur and concentrations of PMC lower than 0·01%, all proved ineffective.

The development of perithecia was studied by sectioning leaves at fortnightly intervals between autumn and spring. Examination of leaves treated with 0·1% PMC in the spring showed that although no perithecia and ascospores were present, structures resembling perithecial cases had been formed containing spores morphologically identical with the conidia of *V. inaequalis*. These conidia were discharged in the wind tunnels and were successfully germinated, but it is not yet known whether they are capable of infecting apple leaves.

Leaves of M.III and M.VIII rootstocks and of the apple varieties Laxton's Superb, James Grieve, Bismarck and Worcester Pearmain, all developed perithicia but ascospore productivity was highest in M.III rootstocks.

Further work on the infection requirements of the fungus, using MM.109 plants in the glasshouse, has emphasized the close relationship between ascospore infection and the environment. It proved

more satisfactory, for example, to promote high humidity with a falling temperature during the establishment of infection, than to maintain leaf wetness by artificial rain at optimum temperatures. Infection was not prevented when the period of leaf wetness was interrupted by a dry period of several hours.

Field trials

Heavy infection occurred on the unsprayed trees in the trial on Cox's Orange Pippin to compare protective and curative spray schedules (see Report for 1959, p. 24). Seven protective sprays and six curative sprays, four post-blossom in each instance, gave almost complete control, and lime-sulphur and PMC were equally effective as pre-blossom sprays.

Apple mildew *(Podosphaera leucotricha)*

Further evidence on M.III apple rootstocks of the effects of DNC/petroleum-oil sprays in controlling primary mildew infection generally confirmed previous results (see Report for 1959, p. 24). Thus both components together were more effective than either alone, especially petroleum oil. In contrast to the 1959 results, however, the combined spray was at least as effective in the dormant period as at bud-burst. This appears to indicate a seasonal influence. Microscopic examination of treated buds again indicated that the sprays did not eradicate the fungus, but limited its spread in the diseased tissues.

A new trial was designed to test different concentrations of karathane in a schedule of five applications and also to compare this chemical and an analogue as dilute and concentrate sprays.

A summer pruning method, ensuring the production of successive waves of young, susceptible shoots and leaves, is being developed to facilitate studies on the infection requirements of the mildew conidia. It is hoped that it may be possible to relate the incidence of mildew on new shoots with weather conditions prevailing at the estimated time of infection.

Apple canker *(Nectria galligena)*

A mercury preparation and two copper preparations were compared for the control of apple canker on M.VIII rootstocks using two sprays in the autumn and one in the spring. At a level of control lower than that usually given by this schedule, no substantial difference was observed between the spray materials. The experiment is being continued.

A bud-rot disease of hazel

Inoculation experiments have now established that this disease is caused by a *Gloeosporium* sp. and they have clarified the disease cycle. A spray programme based on the results of pilot experiments has virtually eliminated the disease from a severely affected commercial cobnut plantation.

Silver leaf *(Stereum purpureum)*

The trial on mature trees to find the effect of removing diseased branches on the growth of the fungus in the wood is still in progress. The trees have been successfully infected and removal of branches will begin when foliage symptoms are judged sufficient to justify remedial action under commercial conditions.

Inoculations of three strains of S. *purpureum* from different hosts into Victoria plum trees have provided evidence of parasitic adaptation by the fungus. Foliage symptoms developed with all strains, but were most intense in trees infected with a plum strain.

The growth of S. *purpureum* was strongly inhibited in culture by *o*-coumaric acid ; this compound and its sodium salt are being tested as injectants.

Gloeosporium diseases *(G. album* and *G. perennans)*

The disease cycle

Studies on spore concentrations in an orchard of Cox's Orange Pippin infected with *G. album* have been continued (see Report for 1959, p. 24). Concentrations increased during the autumn of 1959, reaching a peak in November and then decreasing during the winter. The spore productivity of stubs collected monthly and induced to sporulate in the laboratory, followed a similar pattern. The effect of rainfall and other factors on spore concentrations is being examined. Attempts to relate infection of fruits in the field to specific periods of spore discharge during the growing season were unsuccessful. This was partly due to the fact that the methods used to delimit infection periods by enclosing the

fruits in polythene, or by picking them at different stages before maturity, altered the susceptibility of the fruits.

Apothecia of *G. perennans* have been induced on cankered wood detached from the tree and kept in moist conditions, and fruit has been successfully infected with ascospores from them.

In collaboration with the Plant Protective Chemistry Section attempts are being made to conjugate a fluorescent dye with a specific antiserum for *G. perennans*, the conidia of which are morphologically indistinguishable from those of many other fungi. This should assist in the identification of the *G. perennans* spores in the orchard.

The loading of commercial fruit samples with spores of *G. album* and *G. perennans* (Report for 1959, p. 25) revealed considerable differences in the susceptibility of fruits from different orchards. Comparison with uninoculated samples indicated that the low incidence of rots on samples from some localities was probably due to lack of inoculum in the orchard. No relationship was detected between susceptibility of the fruit and age of the trees.

Verticillium diseases (*V. albo-atrum* and *V. dahliae*)

Host parasite relationships in hops and other plants

In further studies of resistance mechanisms of highly wilt-tolerant hops, other crop plants and weeds, particular attention has been paid to the distribution of suberin and phenolic substances in the young roots. The character most consistently associated with high resistance seems at present to be early and complete suberization of the endodermis. Early suberization of the hypodermis may also contribute to resistance, but this cannot apparently replace the endodermal mechanism. Recent experiments suggest that very high tolerance in new experimental hop varieties may be associated with an unusually early development of suberin in the endodermis of young roots. Previous evidence that hypodermal suberin might be important has not been confirmed.

Although an intense phenolic reaction in roots (Hoepfner-Vorsatz test) is often associated with high resistance to *Verticillium*, e.g. in grasses and plantains, this is not always so. The field bean, *Vicia faba*, gave a very strong reaction, but is only moderately resistant, while various cruciferous species gave no phenolic reactions but seem to be highly resistant.

Severe wilt in tolerant hops

Incidence of wilt in commercial gardens of tolerant varieties (Report for 1959, p. 25) was higher than in 1959, but did not reach the very high levels of 1958. A new questionnaire was circulated to 43 growers of tolerant varieties, but no new instances of severe wilt in these varieties was found.

Tolerance trials of hop varieties

Seven varieties from the Wye/East Malling breeding project were tested at the 30-plant level, and the rest of the infected trial plot was occupied by Wye College breeding material.

Farm trials of new varieties

Records of wilt incidence were made in the farm trials of three new varieties derived from the Wye/East Malling scheme.

Disposal of hop residues from infected gardens after machine picking

This work has been carried out in collaboration with the Department of Hop Research, Wye College, and the N.A.A.S., Wye.

The infectivity of hop waste from a machine-picked tolerant variety, in which 4·7% wilt and 12·7% symptomless infection were recorded at harvesting, was tested in a field experiment using Fuggle N plants as indicators. Waste bine caused 100% infection of the Fuggle N plants and the trash, such as lateral shoots, leaf and cone fragments caused 87% (p. 100).

The time taken *in vitro* to kill progressive *V. albo-atrum* in hop bine fragments ranged from 7 days at 40° C to 15 minutes at 60° C. An experiment was started to determine the survival of the organism in composted hop waste.

Laboratory methods for differentiating tolerant and sensitive varieties

Further tests to explore the possibility of differentiating between varieties by inoculation of excised roots now suggest that the method is unlikely to be successful.

Pathogenicity tests

The pathogenicity of eight monospore isolates of a progressive strain of *V. albo-atrum* was compared with the original parent culture. All monospore cultures, including forms producing no dark mycelium, were highly virulent, although some variations in the rate of wilting were observed.

Studies in the soil relationships of *Verticillium albo-atrum*

Survival in the soil.—In untreated hop soils conidia survived for the maximum period tested (14 weeks) but this result may have been affected by the presence of weed seeds which germinated intermittently during the experiment. In the trial to determine the persistence of the wilt fungus under various cropping and management conditions, there was an increase compared with last year in the number of positive isolations from plots under annual weed cover.

Verticillium wilt of strawberry

A trial of nine varieties has been laid down on a site previously occupied by potatoes in which infection with *V. dahliae* was widespread. Wilt incidence reached 80% in Cambridge Vigour, 38% in Huxley, 36% in Rearguard and about 10% in Mme. Lefebvre. It did not exceed 3% in Favourite, Premier, Sovereign, Merton Princess, and Talisman. Huxley showed some recovery late in the season.

Verticillium in quince and pear

Failure of young pear trees on Quince A rootstocks to establish satisfactorily when planted out in the field appeared invariably associated with infection of the rootstock by *V. dahliae*. There is evidence that the rootstocks may have been already infected when budded without necessarily showing symptoms.

A tolerance trial of five quince rootstocks has continued for a third and final year. Marked dwarfing of the trees (Conference) was associated with two rootstocks. Whether or not this was due to *Verticillium* infection will be determined this winter by anatomical studies after the trees are grubbed.

FUNGICIDE INVESTIGATIONS

Concentrate sprays

Studies of the influence of droplet size on scab and mildew disease control are now being conducted on MM.109 rootstocks in the glasshouse, where closer control of deposit patterns can be ensured. Differing series of droplets of approximately uniform diameter were applied by a spinning disc from a constant volume of lime-sulphur concentrate. Within the limits so far investigated, sprays giving the closest cover of the leaf surfaces, all those with the smallest and most numerous droplets, showed greatest promise for post-infection control of scab and mildew under the experimental conditions employed.

A new field trial was begun on dwarf-pyramid apples to test spray-concentrates of some current organic fungicides on dessert varieties and sulphur sprays on culinary varieties. In a spray experiment against pear scab, Comice fruits were severely russeted by colloidal sulphur applied as a concentrate, and it now seems clear that this variety does not tolerate sulphur either as a dilute or as a concentrated spray. Captan at high, medium or low concentrations provided a much better skin finish.

VIRUS DISEASES OF FRUIT TREES

Apple

Some of the Malling and Malling-Merton clonal rootstocks were found to be infected with viruses that do not cause recognizable symptoms in commercial varieties. One of these viruses induces chlorotic leaf symptoms on several *Malus* hosts, including *M. platycarpa* and Spy 227, while another virus produces the stem-pitting disease on Virginia Crab. *Amelanchier* spp., *Cydonia* sp. *Chaenomeles* sp. and peach are also affected by viruses latent in apple. Selections of M.XII, M. XVI, M.26, Crab C, MM.104, MM.106 and MM.111 were found without latent infection.

Two abnormal forms of Cox's Orange Pippin, one with small fruit and the other with severely russeted fruit were shown to be graft-perpetuated but the cause was not transmissible. They arose presumably from bud sports and not as a result of virus infection.

Pear

The search for a virus-sensitive quince resistant to mildew revealed many sensitive quince seedlings ; the few that remained free from mildew infection are being propagated for comparative trials.

Heat treatment was applied by several methods to pear and quince material with promising results, although further tests are required to confirm complete virus inactivation.

Cherry

Leaf roll disease was identified in newly discovered outbreaks in Kent, Berkshire, and Worcestershire. The virus was readily transmitted from cherry to herbaceous hosts and from tobacco to cherry and strawberry. An antiserum to this virus has facilitated reliable diagnosis and shown that a virus associated with *rozet* disease in the Netherlands is a strain of cherry leaf roll virus.

Investigation by serological methods showed that raspberry ringspot virus was associated with, and probably the cause of, rasp leaf disease in Kent and Berkshire.

The unhealthy condition of many orchard trees of the variety Noble appears to be a virus disease similar to necrotic rusty mottle in North America. The symptoms, leaf yellowing and premature defoliation, accompanied by bud death and gumming, are easily confused with those of bacterial canker. The variety Tradescant's Heart developed these symptoms after inoculation with the virus from Noble.

Plum

Plum pox again developed on the fruit of Warwickshire Drooper trees inoculated with scions from two sources.

Cross-protection tests indicated a high degree of interference between mild and severe strains of plum line pattern virus.

Victoria plum trees with bark split symptoms contained a virus that killed trees of Cambridge Gage in two years.

Virus tested sources of scion varieties for the Mother Tree Scheme

The list of virus-tested material available for distribution was extended by additional varieties of pear, cherry, and plum.

VIRUS DISEASES OF SOFT FRUITS

Strawberry

A technique for the serial transfer of nematodes, *Xiphinema diversicaudatum* (Micol.), from plant to plant was developed for the study of virus transmission by this vector. Arabis mosaic virus was transmitted to petunia seedlings after minimum acquisition and test feeding periods of one and three days respectively ; the nematodes remained infective after periods up to 30 days without access to plants.

All of the 15 strawberry varieties tested were susceptible to arabis mosaic virus. Further varieties are being tested for resistance.

The strawberry green petal virus was transmitted to white clover plants by *Speudotettix subfusculus* (Fall.) ; this is the fourth genus of leafhoppers found to transmit green petal virus. Another virus, closely resembling aster yellows in its effect on Vinca and Delphinium, was shown to affect strawberry plants severely, causing leaf reddening and wilt.

Loganberry and blackberry

Vigorous plants of Bedford Giant blackberry and Thornless Loganberry have been virus-tested and healthy stocks propagated for fruiting trials.

Currants and gooseberry

Black currant reversion and gooseberry vein-banding viruses have been causing serious damage in recent years, and other viruses with less obvious effects may be important.

In a trial planted in 1954 the black currant yellows and vein pattern viruses decreased the weight of the Baldwin crop by 70 and 34% respectively during the period 1957-60 ; comparable losses for Wellington XXX were 71 and 52%. The yellows virus had an obvious stunting effect and decreased both the number and size of the fruits, whereas the less virulent vein pattern virus decreased the size of the fruits but had little effect on their number.

VIRUS DISEASES OF HOPS

Nettlehead

Attempts to infect hop plants with four viruses known to be transmitted by leafhoppers, and one by nematodes, have failed to induce nettlehead symptoms. Nettlehead virus was transmitted in two experiments, however, by inoculating Early Prolific plants with sap extracts of infected hop plants.

The extreme sensitivity of the Early Prolific variety to nettlehead was shown to be due to latent infection with a virus which also increases the severity of the disease in Fuggle and Bramling (p. 106).

Split leaf blotch

Most of the Keyworth's Midseason and College Cluster plants either died or developed symptoms resembling those of nettlehead during the year following infection with split leaf blotch virus. This severe reaction did not occur when these varieties were thus treated in a previous experiment.

Eight clones developed from Fuggle seedlings and three from heat-tested Fuggle N plants are being tested as indicators for split leaf blotch virus.

Mosaic

Large numbers of the hop-damson aphid were transferred to mosaic-sensitive hop plants in an attempt to simulate natural infestations which may be responsible for virus spread. Virus transmission by pollen was also tested.

Yellow net

This new virus disease is described on p. 105.

Publications during the year

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C446 Posnette, A. F., and Cropley, R. (1960). **Virus diseases of cherry trees in England. III. Crop reduction caused by some viruses.** *Rep. E. Malling Res. Sta. for 1959*, 92-5.

C447 Cropley, R., Ellenberger, Christina E., and Jha, Asharfi. (1960). **Strawberry mosaic and apple mosaic virus in strawberry.** *Rep. E. Malling Res. Sta. for 1959*, 96-7.

C448 Posnette, A. F., and Jha, Asharfi. (1960). **The use of cuttings and heat treatment to obtain vitus-free strawberry plants.** *Rep. E. Malling Res. Sta. for 1959*, 98.

C449 Ellenberger, Christina E. (1960). **Heat inactivation of some viruses in plum varieties and rootstocks.** *Rep. E. Malling Res. Sta. for 1959*, 99-101.

C450 Legg, J. T. (1960). **A virus-degeneration of Loganberry.** *Rep. E. Malling Res. Sta. for 1959*, 102-3.

C451 Cropley, R. (1960). **Pear blister canker : a virus disease.** *Rep. E. Malling Res. Sta. for 1959*, 104.

C452 Harris, R. V. (1960). **Progress in research on *Verticillium* wilt and virus diseases of hops in 1959.** *Rep. E. Malling Res. Sta. for 1959*, 132-4.

C453 Talboys, P. W. (1960). **A culture-medium aiding the identification of *Verticillium albo-atrum* and *V. dahliae*.** *Plant Path.*, **9**, 57-8.

C454 Crosse, J. E., Bennett, Margery, and Garrett, Constance M. E. (1960). **Investigation of fire-blight of pear in England.** *Ann. appl. Biol.*, **48**, 541-58.

C455 Billing, Eve, Crosse, J. E., and Garrett, Constance M. E. (1960). **Laboratory diagnosis of fire-blight and bacterial blossom blight of pear.** *Plant Path.*, **9**, 19-25.

C456 Moore, M. H. (1960). **Apple rootstocks susceptible to scab, mildew, and canker for use in glasshouse and field experiments.** *Plant Path.*, **9**, 84-7.

C461 Posnette, A. F. (1960). **The economic importance of virus diseases of fruit trees in England.** *N.A.A.S. quart. Rev.*, **11**(48), 170-5.

VII. ENTOMOLOGY

Natural control of orchard pests

A field experiment to study the interaction of the black-kneed capsid, *Blepharidopterus angulatus* (Fall.), and its prey, the fruit tree red spider mite, *Metatetranychus ulmi* (Koch), was completed. Whilst low mite populations were maintained on plots where the natural balance between predator and prey was undisturbed, the use of DDT, in August 1957, resulted in high mite populations in 1958 ; these were checked by the reappearance of predators in 1959 and brought under control in 1960.

Another trial to investigate the effect of annual applications of DDT-BHC and lead arsenate-nicotine at the green cluster stage has continued for a second year. Apart from the elimination of a predacious bug, *Psallus ambiguus* (Fall.), by DDT-BHC the sprays have had little effect on predators, including *Typhlodromus pyri* Scheut. There is at present no indication that either treatment has caused a marked increase in phytophagous mites.

The toxicity of various fungicides to *P. ambiguus* and *B. angulatus* is being studied in the laboratory with a view to designing a spray programme which will adequately control apple scab and apple mildew without reducing predator populations.

Biology and chemical control of fruit pests

Apple aphids

A study of records obtained during the past ten years has indicated that autumn populations of the apple-grass aphid, *Rhopalosiphum insertum* (Wlk.), may be used to predict the general level of infestation to be expected in the following spring. There is also a good correlation between low autumn populations and drought conditions during the previous summer months, probably through an effect on *Poa annua* L., the summer host.

Codling moth, *Cydia pomonella* (L.)

A mercury vapour light trap has again been used to define the flight period. From larvae overwintered in corrugated cardboard bands in the orchard, adults emerged prematurely in relation to the natural field population, acceleration of development being greatest in exposed situations and least in shaded ones. During a 24-day period adults caged in a partially shaded situation laid more eggs from 0800-1600 hr than from 1600-0800 hr G.M.T.

Field trials have centred on variations in the time of application. The addition of a petal-fall spray of 0·2% lead arsenate to the standard programme considerably reduced the number of larval entries at the calyx. DDT and *O,O*-dimethyl-*S*-(4-oxo-1 : 2 : 3-benzotriazin-3-ylmethyl) phosphorodithioate both reduced infestations by 95% when applied in mid-June, early and late July ; omission of the early spray reduced efficiency by 25% whilst omission of the last spray had a negligible effect. A single application of DDT in mid-June reduced injury sustained up to late August by 76%. Analyses of harvest residues have been undertaken by the Plant Protective Chemistry Section.

Fruit tree tortrix moths

Light traps have been used at East Malling and Kirdford, Sussex, to indicate the flight periods.

In field trials in Sussex DDT, *O,O*-dimethyl-*S*-(4-oxo-1 : 2 : 3-benzotriazin-3-ylmethyl) phosphorodithioate and *O*-1-naphthyl-*N*-methylcarbamate, applied in mid-June, early and late July, against the first summer generation of *Archips podana* (Scop.), gave respectively 69, 97 and 90% reduction of fruit injury at harvest. In another trial, using only the phosphorodithioate, the first two applications gave control, at 92%, of the same order as was obtained with three sprays.

Adults of *Pammene rhediella* (Clerck) have been bred from larvae collected during 1959 and observations on its habits have continued.

Fruit tree leafhoppers

Studies of the apple species have been completed and the results are being prepared for publication.

Fruit tree red spider mite, *Metatetranychus ulmi* (Koch)

With a view to studying the development of resistance the trial at the Essex Institute of Agriculture has now been changed to a comparison, on half acre plots, of the regular use versus an annual rotation of two organophosphorus compounds and two with contrasting chemical structure. The chemicals in

use are phenkapton, dimethyl *S*-(*N*-methylcarbamoylmethyl) phosphorodithioate, 2,4,5,4′-tetrachlorodiphenylsulphone and 2,2,2-trichloro-1,1-bis(*p*-chlorophenyl) ethanol, a double application of each, at petal-fall and three weeks later, giving good control throughout the summer in 1960. The organophosphorus compounds caused a much more rapid decline in mite populations than did the other chemicals, a phenomenon which was also noted at East Malling. Severe russeting and cracking of Cox's Orange Pippin fruits resulted from a petal-fall spray of the last named chemical when applied at 0·034% at East Malling ; only slight injury occurred when a similar spray was applied two weeks later and none was noted on Laxton's Superb in the Essex trial.

Preliminary tests on orchard trees with demeton-methyl have shown that control may also be obtained by soil application.

Bryobia mites

Biological studies have continued. Three species are associated with cultivated fruits ; *B. ribis* Thom., having a single generation between April and June, is found only on gooseberry ; *B. rubrioculus* Scheut, has three generations on apple and pear and may also occur on other rosaceous plants ; *B. cristatus* Dugés lives mainly on herbaceous plants and grasses but will colonize apple and pear in the spring months. Other species on ivy, broom, clover and grasses are also being studied. A closely related mite, *Petrobia latens* Mull., has been noted on cherry and Myrobalan plum in Kent.

Strawberry seed beetle, *Harpalus rufipes* (Deg.)

Trials with aldrin, sprayed on the soil around plants, have continued. A treatment at 5 lb per acre immediately before strawing reduced the amount of damaged fruit by 69% ; in other trials the infestations were too low to evaluate the effect of 10 lb per acre applied just before the blossom period, or 5 lb per acre applied to the edges of a plot at the time of strawing. Tests for off-flavour of processed fruit are being undertaken by other research associations ; the Plant Protective Chemistry Section report the results of analyses of fruit for harvest residue (p. 35).

Of the chemicals which could be safely used during or near the fruiting period none has shown sufficient toxicity in laboratory trials to merit further test in the field.

Black currant gall mite, *Phytoptus ribis* Nal.

Results of the 1959 trial, in which a range of concentrations of fluoroacetamide and 6, 7, 8, 9, 10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3-benzodioxathiepin-3-oxide were applied immediately before the blossom period or towards the end of blossoming, showed that both chemicals were more effective at the latter stage, but only the highest concentration, 0·1%, of each prevented an increase in infestation above the level prevailing before treatments were applied. Neither material was as effective as 0·04% endrin.

The same chemicals have been used in 1960 as in the 1959 trial with the addition of quinoxaline-2,3-trithiocarbonate, but results are not yet available. Leaf chlorosis was observed following applications of 0·05% fluoroacetamide before and after the blossom period ; sprays applied on both occasions reduced yields of the varieties Baldwin and Wellington XXX by one-half. Analyses of harvest residues are being undertaken by the Plant Protective Chemistry Section.

Raspberry beetle, *Byturus tomentosus* (Deg.)

A single spray on loganberry, when the first fruit was colouring, showed 0·05% malathion to be as effective as dimethyl *S*-(*N*-methylcarbamoylmethyl) phosphorodithioate at 0·02% and more effective than the same material at 0·01%.

Laboratory studies of chemicals

Rearing test insects and mites

Cultures of codling moth, the coccinellid, *Propylea 14-punctata* (L.), *Drosophila melanogaster* Meig., the mottled arum aphid, *Aulacorthum circumflexum* (Buckt.), and a non-resistant strain of the fruit tree red spider mite have been maintained. Because of its reported resistance to apple mildew, *Malus hupehensis* (Pamp.) is under test as a possible host for laboratory stocks of the red spider mite.

Laboratory tests of insecticides

These are all joint investigations with the Plant Protective Chemistry Section.

Studies of persistence, under orchard conditions, of chemicals potentially useful against codling moth have been extended. Both the biological activity to day-old larvae and the amount of toxicant

present have been determined for deposits of varying age ; assessment of the ovicidal action of these chemicals has also commenced.

Further information has been obtained on the toxicity, to various predators, of insecticides used before the blossom period on apple and against codling moth.

A start has been made to establish dosage-mortality relationships for foliar deposits of chemicals in common use against the fruit tree red spider mite. When data for normal mites are available it should be possible to follow the development of resistance in the field.

Vectors of virus diseases

Leafhoppers

Life history studies of *Aphrodes bicinctus* (Schrank) and *Loepotettix dilutior* (Kirsch.) on their natural hosts have continued. Laboratory studies on the adult longevity and reproductive potential of *A. bicinctus* are in progress. Chemical control of *Macropsis scotti* Edwards combined with removal of plants infected with rubus stunt, in two commercial plantations of cultivated blackberries, has resulted in a further decrease in the number of new infections.

Identification and provision of insects for virus vector studies by the Plant Pathology Section have continued.

Nematodes

Systematic surveys of the dagger nematode, *Xiphinema diversicaudatum* (Micol.), at two sites in south-east England, have shown that it usually appears to be absent, or present only in very low numbers, in cultivated and pasture land, although moderate numbers occur consistently in the neighbouring hedgerows and woodlands. Occasionally, quite high populations occur under suitable cultivated hosts such as strawberry. The relationship of this distribution to that of arabis mosaic and nettlehead viruses, and similar studies of the genus *Longidorus* in relation to cherry rasp leaf disease, are being investigated in collaboration with the Plant Pathology Section.

Host resistance

(In collaboration with the Pomology Section.)

Woolly aphid, *Eriosoma lanigerum* (Hsmnn.)

One family of seedlings of Northern Spy parentage has been tested for resistance to the aphid and results will be compared with those obtained from an histological examination of the shoots.

Rubus aphid, *Amphorophora rubi* (Kalt.)

Cultures of strains 2-4 have been maintained and tests of raspberry seedlings for resistance to these strains have continued.

Black currant gall mite, *Phytoptus ribis* Nal.

The behaviour of mites on susceptible (black currant) and resistant (gooseberry) seedlings has been studied in order to try and devise a rapid method of forecasting resistance.

In a field plot containing cuttings of *Ribes* species and hybrids, closely interplanted with infested and healthy black currants, no mites were found in the dormant buds of red currant, gooseberry or *R. sanguineum* L. although black currants were heavily infested.

Nematode investigations

Studies on the host-parasite relations of the root lesion eelworm, *Pratylenchus penetrans* (Cobb) and apple seedlings, begun in Canada in 1959, have continued. Primary parasitism by the nematode has been confirmed and its pathogenicity under microbiologically sterile conditions related to the distribution of phenolic compounds in the apple root. A joint paper with colleagues at Harrow, Ontario, is in preparation. Experiments are also being continued jointly to assess the effect of nematode infestations on apple growth.

In a pot experiment, where apple orchard soil was kept free from weeds but not mosses, populations of *P. penetrans* declined to very low numbers within 18 months whereas *P. minyus* Sher. and Allen survived in virtually undiminished numbers for at least 30 months.

In a field trial, on land heavily infested with *P. penetrans*, markedly better growth of strawberry plants and reduced nematode populations have been maintained on plots fumigated, in autumn 1958, with a mixture of 1,2-dichloropropane and 1,3-dichloropropene.

Systematic studies

Phytoptidae

Studies of these mites have continued ; *Acaricalis hederae* (Keifer), a free-living species on ivy, has been recorded for the first time in England.

Publications during the year

D326 Dicker, G. H. L. (1960). **A field study of the spread of apterous forms of the strawberry aphid, *Pentatrichopus fragaefolii* (Cock.).** *Rep. E. Malling Res. Sta. for 1959*, 105-8.

D327 Muir, R. C., and Gambrill, R. G. (1960). **A note on the knock-down method for estimating numbers of insect predators on fruit trees.** *Rep. E. Malling Res. Sta. for 1959*, 109-11.

D328 Collingwood, C. A., and Dicker, G. H. L. (1960). **A comparison of various chemicals for control of the black currant gall mite.** *Plant Path.*, **9**, 39-48.

D329 Goodey, J. B., Peacock, F. C., and Pitcher, R. S. (1960). **A redescription of *Xiphinema diversicaudatum* (Micoletzky, 1923 and 1927) Thorne, 1939, and observations on its larval stages.** *Nematologica*, **5**, 127-35.

D330 Chant, D. (1959). **Phytoseiid Mites (Acarina : Phytoseiidae). Part I. Bionomics of seven species in south-eastern England.** *Canad. Ent.*, Suppl. **12**, 1-44.

VIII. PLANT PROTECTIVE CHEMISTRY

Analytical methods

The method for microbioassay of pesticide residues, using *Drosophila melanogaster* Meig., has been used again to estimate harvest residues of aldrin on strawberry fruits and of 6:7:8:9:10: 10-hexachloro-1:5:5a:6:9:9a-hexahydro-6:9-methano-2:4:3-benzodioxathiepin-3-oxide on black currant fruits. A study of the efficiency of several 'clean-up' procedures has been necessary with black currants to improve precision, and chemical methods of analysis based on total chlorine determinations or sulphur dioxide evolution are also being used.

Techniques for separation of the insecticide, *O*-1-naphthyl *N*-methylcarbamate, from apple wax prior to chemical analysis have been compared ; precipitation of wax from acetone extracts by adding aqueous ammonium phosphate is preferred, and likewise measurement of the final azo-dye colour intensity in acid solution.

An American method of assessing residues of the insecticide-acaricide, *O*, *O*-diethyl *S*-*p*-chlorophenylthiomethyl phosphorodithioate, based on the reaction of 2:6-dibromo-*N*-chloroquinone imine with thiophenol released from the ester by hydrolysis, has been adapted to determine the closely related acaricide, phenkapton, which also releases a chlorinated thiophenol on hydrolysis. The method is much simpler than the only one hitherto available, in which the thiophenol is brominated, reacted with potassium cyanide, and cyanogen bromide finally measured.

Use of insecticides on top fruit

Codling moth

Collaborative studies with the Entomology Section have continued and the persistence has been measured of a number of promising insecticides used not only at the recommended timings but also at petal-fall in an attempt to prevent eye entries. Analyses of deposits in the eye of Worcester Pearmain fruits that had been sprayed either at petal-fall (mid-May) or in mid-June with 0·2% lead arsenate confirmed that at the latter stage this insecticide cannot be introduced into the calyx cup. Harvest residues on Cox's Orange Pippin following two or three applications of lead arsenate, DDT or *O*, *O*-diethyl *S*-(4-oxo-1:2:3-benzo-triazin-3-ylmethyl) phosphorodithioate have been measured, and a paper presenting such data for these compounds and for *O*-1-naphthyl *N*-methylcarbamate is in preparation. Laboratory studies have included parathion, malathion, diazinon, phosphamidon, *O*, *O*-dimethyl *S*-(*N*-methylcarbamoylmethyl) phosphorodithioate, phenkapton and the analogue mentioned above, as well as the materials used in the field trials.

Fruit tree red spider mite

The trial begun in 1959 at Writtle, Essex, was continued. Similar treatments were again applied to half of each of the four plots, but on the other half of each plot, the treatment was changed so that an organophosphorus compound was used where a non-phosphorus type was used before, and a compound active against adults replaced one active against eggs and larvae, and vice-versa. In this way, it is hoped to find out if varying the type of acaricide used in successive years will preclude the selection of tolerant individuals that is expected to follow repeated use of the same compound. Studies of persistence have been made by chemical analysis of all four compounds used in this and in another trial in which demeton-methyl was also used.

Use of insecticides on soft fruit

Strawberry

Harvest residues on fruit following the application of 0·2% aldrin pre-blossom or of 0·1% aldrin before strawing were in all cases less than 0·1 p.p.m. Data on deposits in the soil and on harvest residues have been submitted for publication elsewhere. Half-life values for malathion and *O*-1-naphthyl *N*-methylcarbamate on fruits have been determined ; 1·5 days for malathion and 9 days for the carbamate are similar to the half-life periods found on other kinds of fruit.

Black currant

Data obtained of harvest residues of endrin on fruit, as reported in the 1958 Annual Report, have been submitted for publication elsewhere. Studies have continued on the use of fluoroacetamide and the cyclic organic sulphite, but the results were obscured by frost damage to the crops.

Raspberry

The results of residue studies of malathion on raspberry, loganberry, strawberry and apple are published on p. 116.

Fungicides

Glass-slide studies

Work during the winter 1959-60 confirmed the excellent reproducibility obtained when the toxicant was added to the spore suspension and the mixture then placed on the slides. Compounds giving complete inhibition of germination of conidia of *V. inaequalis* strain E_1, at 10 p.p.m. included captan, dodine (n-dodecylguanidine) acetate, dinex, 2:4-dinitro-6-*n*-heptylphenol, 4-nitro-6-chloro-*o*-cresol, 1:6-dinitro-2-naphthol, and 2:4-dinitro-1-fluorobenzene (FDNB). At 5 and 2·5 p.p.m., only captan, dodine acetate, dinex and FDNB were fully inhibitory, and at 1·25 p.p.m. inhibition by dodine acetate had fallen to 10% and by FDNB to 40%, captan still giving 100%. In contrast to these results, the zinc and iron salts of, and the disulphide derived from, pyridine-2-thiol-1-oxide were still giving complete inhibition at 0·625 p.p.m. and 95-100% at 0·315 p.p.m. ; the only other compound that had given the same performance is the nitrosopyrazole, J49. Captan gave only 10% control at 0·625 p.p.m.

Repeated tests with 2:4-dinitro-6-(1-methylheptyl)phenol, DNOP, have shown that the mean percentage inhibition of germination in fifteen tests in which at least 90% of the spores germinated in the formulation controls, was $80·9 \pm 11·9$ at 10 p.p.m. ; inhibition was complete at 20 p.p.m. In the homologous series, 2:4-dinitro-6-*n*-alkylphenols, a flat peak was found including the *n*-hexyl to *n*-nonyl compounds ; in the isomeric 2:6-dinitro-series, there was a very sharp, but much lower, peak at the *n*-heptyl compound. The effect of modifying chain structure, apart from length, has also been studied.

Chemical control of powdery mildews

The greenhouse accommodation was modified by transferring the settling-towers and sink-bench to a wooden ' laboratory ' compartment at the north end of the house, so enlarging the greenhouse compartment and enabling a third compartment to be created for the production of inoculum. Conditions in the greenhouse compartment were greatly improved, as shown by more satisfactory plant growth as well as by temperature and relative humidity records, by inserting a large extraction fan controlled by a tubular thermostat, and by injecting water into the replacement air entering the compartment. Uniformity trials with barley seedlings and apple rootstocks showed that the development of lesions was not impaired, even when outside temperatures rose very high in June.

Using the small settling-tower for inoculation of young barley seedlings, more than twice as many lesions developed on the one side of horizontally arranged leaves than on both sides of leaves exposed in the usual upright position ; there was no significant difference between the number of lesions developing when the inner (ventral) surface was exposed and when the outer (dorsal) surface was exposed.

A repetition of the heat-treatment experiment with M.III rootstocks in 1958 was carried out with MM.106 rootstocks, and gave a very similar result ; rootstocks heated to 37° C for 4 hr immediately after leaving the tower (24 hr after inoculation) developed only half the number of lesions found on unheated inoculated plants.

The method developed for studies of protective action was shown to be satisfactory for studies of curative action on apple, rootstocks being dipped in aqueous formulations two days or more after inoculation. Thus lime-sluphur at 1% gave 99·8% control when applied after two days incubation ; DNOP at 0·01%, and DNOPC at 0·0125%, also gave over 99% reduction of lesions subsequently appearing, whether applied one day before, or two days after, inoculation.

Crude DNOPC was shown by chromatography to contain more than one fraction that is highly inhibitory to apple mildew.

Dinoseb crotonate, applied in 1953 at 0·05% to rootstocks on an open bench, killed them in 48 hr. It was therefore of interest to compare the closely-related ester, dinoseb dimethylacrylate, currently offered by a German firm as an acaricide. Even at 0·01%, the crotonate used protectively damaged all leaves so that its fungitoxic effect could not be assessed ; at the same rate, the dimethylacrylate caused appreciable damage, though it gave fairly good control of mildew. Applied curatively, i.e. after the plants had been removed from the tower, the latter was less effective in controlling mildew but caused no damage, indicating that the 48 hr in the tower accentuated phytotoxic effects ; the crotonate, however, was still damaging although used at half the rate.

The interesting Netherlands discovery that certain organophosphorus compounds can confer protection against powdery mildew led to studies with one of them, W.P.155. Compared at 0·005% in the same formulation, this product gave 83% control of apple mildew whereas DNOP gave 100% ; control by W.P.155 at 0·01% was 98%, and at 0·02% was 100%, without any sign of phytotoxicity.

The rate of control declined rapidly as the interval between application and inoculation was extended from one day to seven, but 95% control was obtained by 0·01% applied several days after inoculation.

The highly viscous polybutene, H 1500, even at 2% was ineffective in controlling mildew on apple. Fungicides shown to be safe on barley but of no value for mildew control include copper dihydrazine sulphate and the pyridine-2-thiol-1-oxide compounds mentioned above.

Studies of the influence of magnesium, added as the sulphate to soil or foliage, on the incidence of mildew following artificial inoculation were continued on MM.102 rootstocks, in collaboration with the Fruit Nutrition Section (see p. 81).

Field trials

Several small-scale field trials on rootstocks and dwarf pyramid apples were set up in collaboration with the Plant Pathology Section to assess (a) the fungitoxic value of various concentrations of DNOPC,* (b) of DNOP and DNOPC in hydraulic and in atomized sprays, (c) of DNOPC in combination with various fungicides effective against scab, and (d) of low-volume applications of inorganic sulphurs.

Determinations of sulphur in deposits of lime-sulphur have been made where applications were made on paper and on foliage by means of a spinning-disc sprayer provided by the N.I.A.E.

Phytotoxicity

The trial on three apple varieties in which various types of fungicide are applied in different sequences was continued with re-randomization for a third year. Damage to foliage from pre-blossom mercury was again seen on Cox's Orange Pippin. Statistical analysis of the results from the first two years shows that there was no more damage from any one sequence of fungicides than from any other.

The comparison of dodine acetate, 0·07%, and captan, 0·1%, on the seven-variety plot was continued without re-randomization ; dodine acetate caused no loss of crop, but russeting was increased on some varieties.

In mid-summer the foliage on all treatments in the mildew fungicides trial on Lane's Prince Albert suffered badly from a deficiency, probably of magnesium, so that records of mildew infection on spur and extension shoot leaves were not obtainable.

A trial was begun on the four-variety plot of pears to ascertain the effects of DNOPC, DNOP and DNHP (2:6-dinitro-4-*n*-heptylphenol), applied three times post-blossom at rates known to control powdery mildew on apple.

Lime-sulphur, applied once at 2½% pre-blossom and twice at 1½% post-blossom, again caused no damage on Leveller and Lancashire Lad gooseberries. DNOPC, as the commercial wettable powder plus wetting agent, was applied at 0·05% pre- and 0·025% post-blossom without measurable damage.

In a trial for chemical control of black currant gall mite, fluoroacetamide caused a reduction in crop for the second successive year on Baldwin and Wellington XXX.

Several systemic fungicides were applied to Victoria and Early Laxton plum trees at 125 or 500 p.p.m., based on estimated tree weights, by securing cotton-wool pads containing the appropriate dose to the trunk of the tree. As a result of this treatment a severe attack of leaf-curling aphis on Early Laxton was cleared up ; no damage was caused by any treatment on either variety.

Various methods of preparing copper sprays for application to cherry trees were tried in September. Three pints of cottonseed oil per 100 gal. of 4:6:100 Bordeaux mixture failed to prevent defoliation whether the mixture was prepared in the normal or the reverse order, or even with minimal lime.

Publications during the year

Q101 Kirby, A. H. M. (1960). **Agricultural fungicides.** *Rep. Prog. appl. Chem., 1959,* **44,** 299-304.

Q102 ——, and Bennett, Margery. (1960). **Damage on apple by arsenic, copper and mercury sprays : a seven year study.** *Rep. E. Malling Res. Sta. for 1959,* 112-15.

Q103 Allen, M. (1960). **A rapid method of measuring the magnesium content of large numbers of individual leaves.** *Rep, E. Malling Res. Sta. for 1959,* 116-17.

* The common name recently recommended by the British Standards Institute for this compound is dinocap ; as, however, it is not clear whether this will always refer to the crotonate, DNOPC, or will later be restricted to the phenol, DNOP, it has not been used in this report in which so many references to both compounds occur.

IX. FRUIT STORAGE INVESTIGATIONS IN COLLABORATION WITH THE DITTON LABORATORY

Apple manurial trial

There was very little Gloeosporium rotting in the samples of Cox's Orange Pippin apples from the long-term manurial trial stored at 37° F. As a result, the main examination was delayed until May. The beneficial effect of the sward treatment in reducing wastage from Gloeosporium was again clearly shown but the influence of applied nitrogen in increasing rots, apparent in previous years, was just not significant ($P<0{\cdot}1$). With the samples stored at 32° F the apples from the sward treatment had markedly less low temperature breakdown than those from the arable treatment when examined in mid-February. Little wastage from breakdown was also associated with applied potash.

The rate of water loss per week at 40° F was determined for all treatments. This was less in fruit grown with the sward treatment than without it ; no other effects of treatments were found.

Chemical analyses and measurements of respiration at picking time were made at Ditton Laboratory and are being considered in relation to the recorded storage behaviour of fruits from the same treatments. The Biochemistry Section has continued its investigation of the organic acids of the developing and aging fruits from some of these treatments in relation to their storage behaviour (p. 18).

Irrigation

Through the co-operation of the staff at the N.A.A.S. Experimental Horticulture Station at Luddington it was possible to compare samples of Cox's Orange Pippin from an irrigation trial on that station. The treatments comprised watering at three levels of calculated soil moisture deficit, 1 in., 3 in., and 5 in., and an unwatered control. Fruit from two picking dates were supplied, and samples were stored at 32° and 37° F. There was strong evidence that all the irrigation treatments increased the susceptibility of the fruit at both pickings to low temperature breakdown, also that they increased susceptibility of the earlier picked fruit to bitter pit. As there was little evidence of any trends with increasing amounts of irrigation, it is possible that the timing of the applications may be more important than the total amount applied during the season.

Survey of commercial fruit

Cox's Orange Pippin apples from commercial orchards in many parts of the country were again stored at the Station, in air at 36° F until 18th January and in gas (3% oxygen and 5% carbon dioxide) at 38-39° F until 29th February. Losses from Gloeosporium rots were low in the fruit taken from both types of storage. As in previous years, losses from these rots were greatest in fruit from Essex and Kent, from orchards on the lighter soils, and from trees over 20 years old. On the whole there was rather more rotting in the fruit from the two trees in certain orchards that received higher applications of nitrogenous manure than from the two trees with the lower applications. Samples from a number of the orchards, including some with high and low nitrogen, were treated with spores of Gloeosporium by the Plant Pathology Section to test for resistance (see p. 27). Low temperature breakdown caused very little wastage but bitter pit was fairly common, especially in the cold stored fruit. With both troubles, samples composed of large fruit suffered most, and this factor of fruit size, coupled with small crops in the case of damage by bitter pit, was more important than the separate effects of the various orchard factors.

Leaf samples for analysis by the Fruit Nutrition Section (see p. 23) were taken in July. This year the samples were collected from only 12 of the orchards, selecting those of the original 32 sampled in this way that were having the differential nitrogen treatment on 2 of the 4 labelled trees.

The trees raised on M.IX in 1957 from selected scions of Cox's Orange Pippin carried a moderately heavy crop which has been put into cold storage at 36° F. Some bitter pit showed in the 1959 crop after storage and although some selections were more affected than others, the differences may have been influenced by the size of the crop per tree as this was very variable.

Fruit development

Work on the rate and duration of cell division and extension in developing fruits is temporarily in abeyance. A report has been published (T71) presenting results with Cox's Orange Pippin and Miller's Seedling ; with the latter variety it was shown that severe thinning at pink bud stage of blossom

increased both cell size and number. A further report (p. 120) describes observations on cell size and number in relation to fruit size in Cox's Orange Pippin.

Publication during the year

T71 Denne, M. Patricia. (1960). **The growth of apple fruitlets, and the effect of early thinning on fruit development.** *Ann. Bot., Lond., N.S.*, **24**, 397-406.

X. MISCELLANEOUS PUBLICATIONS

T70 Self, B. F. (1960). **Progress in research on fruit crops in 1959.** *Rep. E. Malling Res. Sta. for 1959*, 135-40.

L36 Harris, R. V. (1960). **The role of relation in Applied Biology.** *Ann. appl. Biol.*, **48**, 453-70.

L37 Hoblyn, T. N. (1960). **East Malling Research Station.** *Food Tr. Rev.*, **30**, 71 and 75.

Part III

RESEARCH REPORTS AND REVIEWS

GENERAL

AMOS MEMORIAL LECTURE*

THE PLANT CUTICLE: ITS STRUCTURE AND RELATION TO SPRAYING PROBLEMS

By J. T. MARTIN, D.Sc., Ph.D., F.R.I.C.

Today we meet in tribute to a kindly and well-loved member of East Malling Research Station, the late Mr. Jesse Amos. May I say how much I appreciate the honour of being invited to give this Memorial Lecture : an honour that is shared by Long Ashton. This occasion is especially pleasing to us because it forges a further link between our two Stations. Earlier lecturers have spoken of Amos's outstanding characteristics : of his knowledge of the plant and keenness of observation and of his ability to combine the scientific with the practical aspects of fruit growing. The work I have been asked to describe would, I think, have appealed to him because it represents an attempt to gain a scientific insight into some of the problems met in the field.

The cuticle of the plant is its natural protective surface covering, or skin. Our interest in cuticles stemmed from work, at home and overseas, on the control of pests and diseases. Some years ago Dr. Kearns and I concluded that further progress could not be made until more was known of the levels and physical nature of the dosages of spray chemicals deposited upon plant surfaces. This led to the setting up, with the support of the Agricultural Research Council, of a small team to work on spray deposits in relation to formulation problems and the efficiency of spraying machines. Startling differences in the levels of deposits were found, especially in work on some overseas crops. The nature of the plant surface obviously greatly influenced the effect obtained, but to what extent did plant surfaces differ in waxiness and was the wetting obtained dependent upon the amount or nature of the surface waxes ? The waxiness of leaves thus became our first consideration, but no methods were available for the determination of waxiness and little was known of the nature of leaf waxes.

Further work led us to an examination of the remainder of the natural protective coverings in connexion with the penetration of chemicals. Were the differences in susceptibility to spray damage of varieties of apple fruits related in any way to the natures of their cuticles ? Could unexpected occurrences of phytotoxicity be explained by changes in the protective membranes, induced by environmental or other conditions ? Sometimes damage was associated with the nutritional status of the tree. The influence of varietal, environmental and nutritional factors upon cuticle formation clearly merited investigation, opening up a large field of research.

We have also been interested in the differing susceptibilities of varieties of fruit and ornamental plants to disease. Investigations elsewhere had shown that a thickened cuticle provided a barrier against invasion. The resistance of plants to fungi has also been ascribed, at least in part, to the presence, within the plants, of compounds possessing inhibitory action on the pathogens. To quote from Dr. M. H. Moore's reference to the work of Flood and Kirkham at East Malling and many workers at other centres :

> 'Fruit trees contain chemical agents, sometimes called inhibitors, that are an essential part of the mechanism of disease resistance.'

It seemed worthwhile to investigate cuticles for the mechanical and chemical protection they might afford, and the powdery mildews, although difficult to handle, were selected for the study of the influence of the cuticle on host-pathogen relationships. These fungi live closely in association with the cuticle and epidermal cells and so are likely to be directly subjected to any antifungal activity that the cuticle may possess.

* The Thirteenth Amos Memorial Lecture, delivered at Wye College on 3rd November 1960.

The structure of plant cuticles

Early workers suggested that the cuticles of plants were formed from epidermal lipoid substances which migrated to the surface and oxidized and polymerized to form ' varnish-like coverings '. Priestley defined the cuticle as the layer lying uninterruptedly over the outer walls of the epidermal cells. The cuticle merges into the epidermal cell wall ; because of this, differentiation between the cuticle and cell wall is not easy and, indeed, the term cuticle has been used in different senses in the botanical literature.

The characteristic component of the cuticle was first described one hundred years ago and given the name ' cutin '. Some, but not all, cuticles carry waxes. Our present view is that the cuticle usually is composed of a spongy framework of cutin with waxes embedded within it and protruding from its surface. Pectin and cellulose occur within the cutin layer. Plasmodesmata, which are protoplasmic outgrowths from the underlying cells, reach towards or into the cutin layer through a zone of concentrated pectinaceous material. The cuticle holds the leaf intact, the wax and cutin conserve water and nutrients, the pectin and cellulose permit cuticular respiration and the cutin is believed to shield the underlying tissues from excessive ultra-violet radiation. Considering the importance in the plant's economy of the cuticle as a whole, it is surprising that comparatively little chemical work has been done on it.

The chemical nature of waxes and cutin

In classical researches in the early 1930's, Chibnall and Piper and their co-workers obtained and characterized mixtures of long-chain paraffins, alcohols and ketones from the waxes of leaves and fruits. *N*-nonacosane, *n*-octacosanol, 15-nonacosanol and 15-nonacosanone may be cited as typical compounds. More recently Matic in South Africa has isolated from the cutin of a fibre-plant leaf a mixture of hydroxylated octa- and hexa-decanoic acids, among which phloionolic acid predominated. Recent work on apple skins by Huelin in Australia has confirmed that cutin is a poly-ester, the cutin acids being readily released on saponification.

Chibnall and Piper obtained their waxes by precipitating them with acetone from concentrated plant extracts. Other workers have since differentiated between the hard or true wax precipitated by acetone and the soft wax or oily material remaining in solution in the solvent. The oil fraction of apple fruit waxes has recently been shown by Davenport in Australia to contain saturated acids, chiefly stearic and arachidic. We are also interested in fruit cuticle problems, but I propose to confine myself largely to our investigations on leaves.

The fractionation of leaf cuticles

It was clear that, if worthwhile progress were to be made, quantitative chemical methods for the fractionation of the cuticles were required. When removing surface waxes, it was necessary to ensure, so far as possible, that no contamination occurred with fatty materials from within the leaves. Four successive quick immersions of leaves in different solvents at room temperature removed differing amounts of waxy substances. The solvents were selective in action, the least effective ones removing chiefly the true wax fractions of the surface deposits. Chloroform was the most efficient solvent ; the fourth immersion removed only small amounts of waxes, but further exhaustive extraction gave appreciable amounts of fatty materials. If leaching were occurring, more material might have been expected in the fourth wash. The immersion method therefore seemed satisfactory for the recovery of the surface waxes. Further restricted hot chloroform extraction gave an indefinite fraction, sometimes contaminated with chlorophyll, that we have called absorbed waxes.

By treating the waxes with dilute alkali, an acidic fraction containing phenolic compounds was obtained, leaving the true wax and oil. The separation of the wax from the oil by acetone precipitation was unsatisfactory, and an improved method using partition between *n*-heptane and methanol was devised.

After the removal of the surface and absorbed waxes, the leaves were further treated to isolate the cuticles. Discs were extracted with methanol to remove pigments and then with ammonium oxalate-oxalic acid solution to remove pectin. At this stage, the cuticular membranes loosened or floated off, and those from the upper and lower surfaces could be obtained separately. The break occurred, not as expected along the pectin zone separating the cutin layer from the epidermal cell wall, but between the epidermal cells and the mesophyll tissues. After cleaning up the membranes with dilute acid and alkali, the attached cellulosic remnants of the epidermal cells were removed by treatment with cuprammonium solution, leaving thin, translucent sheets consisting largely of cutin. These were saponified and the cutin in them was determined from the recovered cutin acids. Microchemical tests on isolated membranes of the *Euonymus* leaf gave positive reactions for both cellulose and pectin

within the cutin layer. The fractions obtained in the analyses were weighed and the results expressed as $\mu g/cm^2$ of leaf surface.

Waxes and cutin on leaves

The surface waxes and cutin on the leaves of different plants vary very considerably. Some leaves, for example those of turnip and red beet, are virtually wax- and cutin-free. The cauliflower leaf is characterized by appreciable deposits of waxes but little cutin. The deposits of both waxes and cutin on apple fruits are about ten times those on the leaves, and the waxy layer on a greasy apple, such as Monarch, is about double that on a relatively non-waxy apple such as Cox. The separate isolation of the upper and lower cuticular membranes of leaves permitted the determination of cutin in the upper and lower surfaces. Without exception, more cutin has been found in the upper surface than in the lower, which accords with textbook accounts of the relative thicknesses of the upper and lower leaf cuticles.

The immersion of leaves in solvent gave the waxes from both surfaces, but we wished to obtain the waxes from the surfaces separately, because the upper and lower surfaces of leaves often respond differently to a spray. This was done by protecting the upper, or lower, surface with a film of synthetic resin, insoluble in chloroform, before immersing the leaves in the solvent. The results were quite interesting. More waxy material was present on the lower than on the upper surfaces of apple and black currant leaves. The increase on the lower surface of the apple leaf was due to a greater secretion of true wax ; on the under surface of the black currant, to an increase in material removed by alkali in the fractionation. The upper surface of apple, and of many other leaves, is glossy and the lower surface dull, reflecting the differences in the composition of their waxes.

Another interesting observation was made in work on the waxes and cutin of healthy and diseased leaves. Puzzling results were obtained until comparisons were made between leaves of comparable size showing the disease and others not visibly affected. Mildewed apple and turnip leaves showed higher waxy deposits than apparently healthy leaves and the cutin was considerably depressed. An examination was then made of healthy and scabbed leaves of an ornamental species of *Malus* and of healthy and virus-mottled leaves of a cider apple variety. Scab infection was visible only on the upper surface of the affected *Malus* leaves and here the cutin was markedly reduced ; the cutin on the lower surface was unaffected. Once more, the deposit of surface waxes was higher on the scabbed than on the apparently healthy leaves. The virus-mottled cider apple leaves showed no differences from the symptomless leaves in the surface and absorbed waxes or in the cutin on the upper and lower surfaces. Many years ago Dr. Wiltshire at Long Ashton reported from histological work the degradation of the cuticle by the scab fungus and this has now been confirmed quantitatively.

It seemed that the mildew and scab infections stimulated the secretion of waxes by the leaves, but to be certain we had to find to what extent the fungus itself was contributing waxy material. Information was obtained from rose mildew, which could be brushed from affected rose leaves leaving clean, polished surfaces. The brushed diseased leaves showed higher deposits of surface waxes than the apparently healthy ones and the mildew infection itself contained waxy material equivalent to 7 $\mu g/cm^2$ of surface. The cutin in the mildewed rose leaves also showed a depression to 25% of its level in the healthy leaves.

Leaves of different ages react differently to sprays, so the changes in the levels of surface waxes were followed during the period of leaf expansion and beyond. Cutin determinations were also made. The levels of surface waxes and cutin fell or remained stationary over the period when the leaves were about half fully grown. At this stage, waxes and cutin secretion failed to keep pace with the rapidly expanding leaf surfaces. After the leaves were fully grown, the waxes and cutin levels remained approximately constant or showed a tendency to decline as the leaves grew older. The period of leaf expansion is clearly one of considerable productivity so far as waxes and cutin are concerned ; the cutin of an individual apple leaf, for example, increases from $\frac{1}{3}$ mg in the young leaf to 3 mg or more in the fully grown leaf. Examinations of this kind were made early in our investigations, and in all subsequent work care was taken to use only leaves from comparable positions on shoots.

Tests are often made on plants raised for convenience in the glasshouse, on the assumption that they will be comparable with plants grown outside. Comparisons of the cuticles of indoor and outdoor plants were therefore of some interest. Apple rootstocks responded to the conditions under glass by producing leaves, when fully grown, 30% larger than those outside, but no significant differences were found in the levels of surface waxes, in their composition or in cutin between leaves under glass and in the open. Apple varieties showed less enhanced leaf growth, and again no significant differences in cuticles between plants indoor and outside were found. It seemed that the deposits formed per square centimetre of leaf surface were characteristic of the variety and were largely unaffected by environmental factors. This work, however, needs to be repeated under more carefully controlled conditions.

Work on the effects of nutritional conditions upon the waxiness of apple leaves (work which also needs considerable extension before a true picture is obtained), indicated reduced levels of waxy deposits on nitrogen-deficient leaves. Other deficiency conditions had little effect.

The suggestion has been made from time to time that full-coverage washes of high wetting efficiency may wash the waxes from leaves, rendering them more susceptible to damage by spray chemicals. This also has been investigated. Worcester and Cox apple trees in the orchard were forcefully sprayed with a commercially-used succinate wetter solution. No differences were found in the surface waxy deposits on leaves of comparable age taken immediately before and after spraying.

Considerable attention has been given to the role that the cuticle might play in conferring upon a plant resistance to disease. Consideration has been given to cuticle thickness as a mechanical barrier to invasion and to the possibility of the occurrence of antifungal agents within the cuticle. On the subject of the cuticle as a barrier to infection, we have obtained interesting data in work on lime leaves from Zanzibar. The young leaves are highly susceptible to *Gloeosporium limetticola*, but when about three weeks old they harden and lose their susceptibility to the fungus. The cuticles of the young, borderline and resistant leaves were therefore compared. Susceptibility to the disease was lost when the leaves were three-quarters fully grown. At this stage the waxes were almost fully formed but the cutin in both the upper and lower surfaces was only one-third of that in the cuticles of the older resistant leaves. The borderline leaves showed a mean level of cutin of about 70 $\mu g/cm^2$ of surface.

Powdery mildews flourish on leaves that are fully grown and that carry cuticles of considerable thickness, but it is clear that the infections occur at early stages in leaf development. With apple, this was beautifully demonstrated by Dr. Burchill. In comparisons of the cuticles of leaves of Bowden's Seedling (highly susceptible to mildew) and of Worcester (relatively immune), we therefore examined leaves at the earliest possible stage in their development. No differences in cuticle components were found, neither were any detected in the examination of leaves that were too small to permit measurements of their surface areas. Comparisons were also made of older leaves of strawberry varieties susceptible and less susceptible to strawberry mildew, and of rose leaves which showed marked differences in susceptibility to rose mildew. No differences were found in the contents of cuticle components, including phenolics, that might account for the differences in susceptibility.

To what extent were antifungal agents present in the cuticles? The initial stage in mildew infection consists in the germination of spores on the plant surface, and so the surface waxes and their wax, acidic and oil fractions were tested for their ability to inhibit germination. Ether-soluble acidic fractions of both Worcester and Cox apple leaves showed fungistatic activity. A similar action, on *Cladosporium*, was exhibited by a corresponding acidic fraction from tomato leaves. This finding was not new; Ezekiel and Fudge in the U.S.A. in 1938 showed that extracts from the roots of certain monocotyledonous plants immune to a root rot fungus contained ether-soluble acidic material which prevented the growth of the fungus. Other fractions of our surface waxes had little effect or stimulated germination.

The work has now been extended to other components of the cuticle. Using cuticle fractions from resistant and susceptible varieties of apple, strawberry and rose leaves in tests on their mildews, strong activities were shown by the absorbed waxes and cutin acids. The effects of the cutin acids were not specific; those from the apple leaf, for example, showed marked toxicity also to the spores of strawberry and rose mildews. A fungitoxic action was seen, as opposed to the fungistatic action of the surface acidic fractions.

General conclusions

Two aspects of the work, to my mind, hold the greatest significance. The first is the development of analytical methods for the examination of cuticles and the second is the extent to which the plant itself has now been included in considerations of crop protection problems. In pest and disease control work we have tended to think rather too much in terms of the chemical and the insect or fungus, while regarding the plant largely as the substrate for the organism. Apart from the influence of its surface on the deposition of sprays, the plant may play a part in the efficiency and mechanism of action of spray chemicals. You may recall our conclusion of a few years ago, arising from the cuticle work, that the leaf contributes to the action of copper fungicides, a finding that was also made by Professor Wain. The plant may affect our crop protection chemicals, and these may also affect the plant, sometimes in surprising ways. Juniper and Bradley and Pfeiffer and his colleagues, for example, have shown that soil treatment with TCA or dalapon reduces the waxy deposits on leaves.

To what extent does our present knowledge of the nature of the leaf cuticle help in unravelling problems met in the field? The ability to wet a leaf does not seem to depend solely upon its degree of waxiness, neither have correlations so far been found between the proportions of the components of the surface waxes and ease of wetting. The physical nature of the waxy deposit rather than its amount

or chemical make-up seems to be the operative factor, a conclusion also reached by Juniper and Bradley. From the practical aspect, it is important that, so far as possible, the formulation of the chemical should be designed to suit the surfaces treated.

Some time ago, discussion centred around the relative importance of the cuticle and stomata in the penetration of chemicals, but the consensus of opinion now favours the cuticle as the main route of entry. As the surface waxes influence wetting, so the cutin seems to govern penetration. When wetted, the spongy framework is believed to open up and penetration to be facilitated; when dry, to constrict and penetration to be impeded. The pectinaceous material within the cutin layer may also play a part. Roberts, Southwick and Palmiter in the U.S.A. in 1948 concluded from microchemical tests that the cutin of the cuticle of the McIntosh apple leaf occurred in lamellae and that pathways of pectinaceous material through the cutin aided the entry of chemicals. The plasmodesmata may also provide pathways from the cuticle to the internal cellular tissue. We have examined penetration through isolated cutin membranes and through membranes with superimposed wax fractions. These, however, differ appreciably from those on the leaf ; tests with living leaves are necessary to obtain a true picture.

What of practical applications ? The postulated reaction of the cutin to moisture may well explain, at least in part, some of the occurrences of phytotoxicity under wet conditions. From work on the cuticles of apple fruits in relation to damage by mercury, the amount of cutin in the cuticle did not seem to be a decisive factor, but rather its degree of dilution in the cutin layer with other materials, among which, in addition to pectin and cellulose, inorganic compounds, sugars and protein have to be considered. If we knew more of the factors influencing penetration it might be possible, by modifications in formulation, to assist the entry of chemicals that should go in and to restrict the penetration of those that should not.

On the role of the cuticle in host-pathogen relationships we are still groping. An inhibitory effect on the fungus may occur on the surface if the acidic fraction is present in sufficient amount and can overcome the stimulatory action of other fractions of the waxy covering. Considerable fluctuations occur in the composition of the surface waxes that we have not been able to relate to losses by leaching. The surface layer seems to be in a state of change ; Juniper has also concluded, from electron-microscope studies, that the belief that the material external to the epidermal cells is static can no longer be held.

The invasion of a resistant plant by a powdery mildew may be halted on the surface, within the cuticle or within the epidermal cells. Some workers have concluded that the inability of the fungus to become established is due to the secretion, by the fungus, of a toxin which kills the epidermal cells. Others have shown that the plant may react to infection by producing mucilage which blocks the mildew haustoria. The role of proteins in disease resistance has been examined and a fungal food hypothesis has been put forward which, if it can be substantiated, may have a bearing upon the puzzling question of fungus-host specificity. Interesting work by Kirkham and Flood at East Malling relates resistance to a favourable phenolic/amino nitrogen ratio within the leaf.

Walker and Stahmann have reviewed the reports that have been made of the presence in a resistant variety of plant of a fungitoxic material not found to the same degree in a susceptible variety. They show that the host-pathogen relationship is complex and point out that the presence in the plant extract of a material that is toxic to the fungus does not necessarily account for the resistance of the host. To exert its effect, the antifungal agent must be present in sufficient concentration of an active form and must be contacted by the invading pathogen. What of the effect of the absorbed waxes and cutin acids ? Our fractionations of cuticles have indicated that the true wax tends to be concentrated on the surface and the acidic material to be more deeply seated, and that cutin layers yield 50-80% of cutin acids. In passage through the cutin layer, the infection thread is therefore in contact with potentially toxic material in high concentration. Are the cutin acids liberated from the cutin by fungal esterase as infection proceeds, and do they affect the fungus or even the epidermal cells ? The cutin acids isolated from resistant and susceptible varieties were equally toxic to the mildews when tested *in vitro* ; if the acids *are* liberated from the cutin by the mildews, are they immobilized in some way in the susceptible hosts ? With pressure on us to control disease, we tend perhaps to become disease conscious, but to me, the remarkable thing in looking around is the comparative freedom from fungal diseases of vegetation of all kinds in fields, hedgerows and woods. That natural inhibitors, including possibly the cutin acids, play a part in protecting plants from fungi can be accepted. From our experiences with cuticles and powdery mildews the problem may be not so much to explain resistance as to account for the phenomenon of susceptibility.

I acknowledge my indebtedness to my colleagues engaged with me in this work, Mr. R. F. Batt and Miss M. F. Roberts (Boots' Scholar 1957-59). We are also grateful for the help given us by Dr. R. T. Burchill and for assistance from Mr. O. S. Peries, a post-graduate worker from Ceylon.

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POMOLOGY

STIMULATION OF FRUIT DEVELOPMENT IN FROST DAMAGED PEARS

By IRENA MODLIBOWSKA

The parts of a pear flower most susceptible to frost are the placenta and the ovules. When either of these vital parts is killed, no seeds can form and thus as a rule no fruit develops, unless it receives a stimulus from some growth substances. In preliminary experiments at East Malling and elsewhere (1,2) gibberellic acid (GA) and 2,4,5-trichlorophenoxypropionic acid (2,4,5-TP) appeared promising for inducing parthenocarpy. They were therefore used in the following experiments.

Experimental material and results

Experiment 1.—Fourteen 6-year-old Conference and Laxton's Superb trees on Quince C had all their flowers decapitated at the white bud stage to prevent pollination (all the styles, stamens and petals were removed with a single cut). On the same day the following treatments were applied in the form of an aqueous spray: (a) GA at 100 p.p.m., (b) 2,4,5-TP at 25 p.p.m., (c) Control —0·01% Mannoxol—the wetter added to all the treatments.

Thirteen days later, on 27th April 1960, when pears were at the petal-fall stage, a frost of 26° F (−3·3° C) in the screen killed over 90% of the flowers. To save the already blackening flowers the treatments were repeated. The trees of Treatment (a) received GA at 50 p.p.m. and those of Treatment (b) were resprayed with 2,4,5-TP at 25 p.p.m.

The effect of treatment showed clearly one month after full bloom. At that time Conference and Laxton's Superb sprayed with GA had set 69% and 47% of their blossoms respectively, and those treated with 2,4,5-TP set 33% and 2% respectively, while the Conference controls set 2% and controls of Laxton's Superb set nothing. At harvest the GA treated trees of both varieties gave a very heavy crop (Table I). The fruit size was consequently reduced but the percentage of marketable fruits over 2 in. in diameter was very much higher than in the other treatments.

TABLE I

EFFECT OF DOUBLE SPRAYS WITH GA AND 2,4,5-TP ON FRUIT SET OF DECAPITATED PEAR BLOSSOM

Treatment	Conference			Laxton's Superb		
	Fruit set %	Marketable fruits per 100 flowers	lb/tree	Fruit set %	Marketable fruits per 100 flowers	lb/tree
GA	30·4	14·7	19·3	24·1	9·3	7·4
2,4,5-TP ..	8·2	4·7	6·5	0·8	0·7	0·8
Control	0·5	0·4	1·0	0·0	0·0	0·0

The lack of fruit set on the controls, even in the variety Conference, which is reputed to have the ability of developing seedless fruits, indicates that fruit setting even in Conference requires the initial stimulus of fertilization and perhaps of endosperm development. This stimulation could not have occurred in the flowers that were decapitated early but was presumably provided by the GA treatment.

This hypothesis is supported by a survey of the proportion of seedless Conference fruits in other years. It was found that in 1950, '56 and '58, when frost occurred at the green cluster stage or before full bloom, the percentage of seedless fruits was 6%, 2% and 10% respectively. In 1959 and 1960, however, when frost occurred at the fruitlet and petal-fall stages, the percentage of seedless fruits rose to 49% and 72%.

Experiment 2.—On 28th April 1960, one day after the critical frost, another experiment was made

on six 9-year-old Conference trees on Quince A. Most flowers were at the petal-fall stage and over 90% of them were severely damaged by frost. Four treatments replicated three times were applied to half-trees as single sprays of the following : (a) GA at 50 p.p.m., (b) GA at 50 p.p.m. + 2,4,5-TP at 25 p.p.m., (c) 2,4,5-TP at 25 p.p.m., (d) Control — 0·01% Mannoxol (as added to all treatments). The results are shown in Table II.

TABLE II

EFFECT OF SINGLE SPRAYS WITH GA AND 2,4,5-TP FOLLOWING FROST ON FRUIT SET PER 100 FLOWERS OF CONFERENCE PEAR

	GA	GA+2,4,5-TP	2,4,5-TP	Control
Total fruit set %	9·7	8·1	7·0	5·8
Marketable fruit % ..	6·4	4·0	5·1	4·9
Frosted blossom set % ..	8·6	6·3	4·5	1·4

The control trees produced 5·8 fruits per 100 blossoms, compared with 9·7 from those sprayed with GA, and although some of the fruits in all treatments were unmarketable, in marketable fruits the GA treatment was still 30% better than the controls. An even more striking point is shown by the fruits produced from frozen blossom (i.e. the fruits that were found to be seedless at picking time). From frozen blossoms, only 1·4% of fruits formed on the control trees, while from the GA treated blossoms, 8·6% fruits formed—about 6 times as many. This is the proportionate increase that might be expected if all, instead of 92% of the blossoms had been frozen.

Experiment 3.—Gibberellic acid (50 p.p.m.) and 2,4,5-TP at 25 p.p.m. were also applied one day after frost to individual branches of single 9-year-old trees of five other pear varieties on Quince A. Control branches were left unsprayed. Durondeau and Williams' responded to the growth substances similarly to Conference (Table III). Beurré Hardy set very few fruits, most of these being on the GA treated branch. On Laxton's Superb the control branch set most fruits, because it was least damaged by frost. In this variety also, however, the GA treatment was the most effective in stimulating the development of frosted flowers into seedless fruits. Comice was still in bloom at the time of frost, so that it suffered less damage (57%) than the other pear varieties ; it showed least response to GA and 2,4,5-TP. It is notable that during the 5-year survey this variety produced the lowest proportion of seedless fruits (mean 1·6%).

TABLE III

EFFECT OF SINGLE SPRAYS WITH GA AND 2,4,5-TP FOLLOWING FROST ON FRUIT SET IN PEARS

Variety	GA		2,4,5-TP		Control	
	Marketable fruits per 100 flowers	% seedless fruits	Marketable fruits per 100 flowers	% seedless fruits	Marketable fruits per 100 flowers	% seedless fruits
Conference	6·4	81	5·1	56	4·9	19
Durondeau	4·6	66	1·8	100	0·9	0
Williams'	7·8	57	2·9	21	2·4	8
B. Hardy	1·0	43	0·4	50	0·4	0
Laxton's S.	4·0	30	0·7	0	6·4	6
Comice	4·0	0	1·4	8	5·5	2

Discussion

Frost after full bloom may induce seedless fruit development in some pear varieties. These fruits, however, have a lower commercial value than those with seeds, because they are often misshapen, e.g. sausage or banana shaped in Conference and thick necked in Durondeau.

Gibberellic acid, whether applied before (Table I) or after flowering (Table II) may induce seedless fruit development in several pear varieties. It may act as a substitute for the growth substances that are normally activated following pollination and fertilization, and also may carry this stimulus over the June drop and induce a heavy crop. A high proportion of these fruits was of good marketable size

and shape, though often somewhat tapering towards the calyx. The greater the natural ability of a given variety to set seedless fruits, the more readily it responded to the application of GA, for example Conference and Durondeau set well after GA treatment while Comice did not respond to it.

Differences were found not only between the reaction of various varieties to GA treatment, but also between stages of development and the method of application of GA within one variety (cf. Laxton's Superb in Tables I and III). There are many factors affecting the response of pear blossom to GA treatment. The amount of GA absorbed seems to be of prime importance. The GA concentration, amount applied, and in particular fresh wounding greatly increased the amount and rate of absorption. Prevention of normal seeded fruit development removes competition and may also affect the reaction of the flowers to GA. The optimal GA concentration varies for different pear varieties and at different stages of floral development. The concentration must be high enough to stimulate fruit development of a proportion of flowers sufficient for a good crop of marketable fruit, but not so high as to cause excessive set of reduced quality fruit leading to exhaustion of the tree. Further research on these points is needed. It is already clear, however, that treatment of frosted pear blossom with gibberellic acid may have commercial possibilities.

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Summary

The effect of gibberellic acid and 2,4,5-trichlorophenoxypropionic acid on the development of frost damaged pear flowers into fruits was investigated. GA proved most promising in stimulating seedless fruit development in several varieties both when applied before or after flowering. GA treatment may have commercial possibilities and requires further research.

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HIGHER BUDDING OF APPLE ROOTSTOCKS

By N. G. SMITH and W. S. ROGERS

In their work on the collar rot disease of apples caused by the soil-borne fungus *Phytophthora cactorum* (L. & C. Schroek), Sewell and Wilson found that certain scion varieties, notably Cox's Orange Pippin, were very susceptible to infection and that many clonal rootstocks were highly resistant (2,3,4). Severe outbreaks of the disease occurred only where susceptible tissues were near the ground. They therefore suggested that susceptible varieties should if possible be worked on resistant stocks at a height of not less than 12 in., which their observations showed would largely avoid the risk of infection. Woodhead (6) in New Zealand, advocated 30 in. as a safe height for grafting susceptible varieties. This would necessitate growing the rootstock for a second year in the nursery row, under English conditions. Budding lined-out rootstocks at 12 in. is possible in the first year, however ; and to test the practicability of this operation, two experiments were carried out, in 1958 and 1959.

Material and method

Trial I.—A hundred and eighty lined-out rootstocks of M.II, and a similar number of M.VII, were budded with Cox's Orange Pippin buds from virus-tested trees. Sixty buds on each rootstock were inserted at heights of 6, 9 and 12 in. respectively from ground level on 11th August 1958. The buds were tied with polyvinyl chloride strips and petroleum jelly was smeared over the cut. *Trial II*, budded 18th August 1959, was similar but included 180 stocks of MM.104 as well as of M.II and M.VII. Each trial contained six randomized blocks of 10 tree plots of each budding height.

Results

Table I shows the percentage of bud-shields that survived. Within each rootstock group none of the figures differ significantly. In 1958, however, the plots were found to have been sited on land that contained infertile strips (5) ; most of the dead bud-shields occurred in these strips, which particularly affected the M.II rootstocks budded at 12 in. On fertile land budding at 12 in. was just as successful as at 6 in.

TABLE I

PERCENTAGE MORTALITY OF BUD-SHIELDS OF COX'S ORANGE PIPPIN INSERTED IN ROOTSTOCKS AT DIFFERENT HEIGHTS

			Budding height		
			6 in.	9 in.	12 in.
Trial I	1958	M.VII	3·3	1·6	4·9
		M.II	18·3	11·6	26·6
Trial II	1959	M.VII	14·9	18·3	9·9
		M.II	11·6	11·6	11·6
		MM.104	0·0	0·0	0·0

None of the differences within rootstock groups are significant, see text.

The nurseryman is concerned with the height his maiden trees attain. It is shown in Table II (column(e)) that the maiden height is increased with each increase in budding height, and that the trees budded at 12 in. were 3½ to 5 in. taller than those budded at 6 in. This difference is significant at the level $P<0{\cdot}001$. In growth of the maiden stem there is a small tendency in the reverse direction, i.e. for the higher budded trees to make less new growth, but the reduction is much less than the extra length of rootstock stem.

The growth of trees in Trial I was predominantly a reflection of the soil condition, and the data are therefore omitted ; but the means did not differ markedly from the figures obtained from Trial II.

TABLE II

MEAN HEIGHT OF 1-YEAR-OLD COX TREES IN 1960, AS INFLUENCED BY HEIGHT OF BUDDING

Rootstock	Height of budding (in.)	No. of healthy trees (out of 60)	Mean growth of maiden-stems from the union (in.)	Mean height of trees from the ground (in.)	Increase in tree height achieved by budding higher than the conventional 6 in. (in.)
(a)	(b)	(c)	(d)	(e)	(f)
M.VII	6	46	52·0	58·0	—
	9	45	51·6	60·6	2·6
	12	50	51·0	63·0	5·0
M.II	6	50	48·5	54·5	—
	9	52	48·6	57·6	3·1
	12	52	46·2	58·2	3·7
MM.104	6	55	50·5	56·5	—
	9	54	49·1	58·1	1·6
	12	52	48·2	60·2	3·7

Bracketed figures in columns (d) and (e) are not significantly different at $P<0.05$.

Discussion

It has been found in two years that it is perfectly feasible to bud rootstocks M.VII, M.II and MM.104 at heights of either 9 or 12 in., and that this gives trees that are slightly taller than those budded at the traditional 6 in. The survival or ' take ' of buds was also just as good at 9 or 12 in. as at 6 in., provided the nursery soil conditions were satisfactory. Thus budding varieties that are susceptible to collar rot, such as Cox's Orange Pippin, at a height of 12 in. can be recommended as sound nursery practice likely to minimize the incidence of collar rot. Budding at 12 in. will also completely eliminate the risk of scion rooting, which still occasionally occurs when trees budded at 5 or 6 in. get slightly earthed up, or surrounded by rough grass, in commercial orchards.

It may be noted that the slightly smaller diameter of the rootstock at 12 in. than at 6 in. led to no difficulty in these trials, even with the rather thin M.II rootstocks ; but if a batch of rootstocks is thinner than 5 mm. diameter at the budding height, it may be advisable to leave them to thicken further until the end of August. When it is intended to bud at 12 in., the rootstock should be headed back higher than usual. In Trial I they were headed at 15 in. above ground level and in Trial II at 18 in., but 20 in. is suggested as even better.

The effect, on the later growth of the tree, of an increase of 6 in. in the length of rootstock stem is unlikely to be large. Beakbane and Rogers (1) found that the rootstock stem slightly intensified the rootstock effect, but its influence was very small compared with that of the roots. With vigorous rootstocks little or no difference would be expected, because most scion varieties are themselves inherently vigorous. With dwarfing rootstocks the dwarfing effect would tend to be slightly increased.

The scion variety for which high budding is most important to avoid collar rot, is Cox's Orange Pippin. Other susceptible varieties are Ellison's Orange, Bramley's Seedling and Lane's Prince Albert (2) and the disease has also been found in James Grieve and Kidd's Orange Red. Rootstocks that are very resistant to collar rot include M.VII, M.IX, M.II, M.XXV, MM.106, MM.111 and MM.104 (4).

It is pleasant to find that the simple modification of nursery practice suggested by Sewell (2) to avoid a potentially serious disease, does in fact also produce better maiden trees.

Acknowledgements

We wish to thank members of the Nursery staff for their help in these experiments.

Summary

In two experiments budding Cox's Orange Pippin at 9 or 12 in. above ground level gave an equally good ' take ' of buds as budding at 6 in., and resulted in taller maiden trees. Budding varieties susceptible to collar rot (such as Cox's Orange Pippin) on to resistant rootstocks at 12 in. is likely to ensure avoidance of this disease, and will also entirely eliminate scion rooting.

Budding apples, particularly those susceptible to collar rot, at 12 in. above ground level, is therefore recommended as a nursery practice.

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Addendum

Since this paper was written, Atkinson and Mouat, in a new review of height of budding in New Zealand (*Orchardist, N.Z.*, **33,** 335-53, Dec. 1960) have recommended budding Cox's Orange Pippin at 20 in. high. This is possible in the first season in New Zealand, owing to the good growing conditions. They state that all trees of Cox's Orange Pippin raised in the New Zealand Fruitgrowers' Federation Nursery are now worked at about 20 in.

DELAYED FLOWERING OF TREES RAISED FROM ADVENTITIOUS SCIONS

By R. J. GARNER and E. S. J. HATCHER

Cultural practices, such as severe pruning or invigoration by the use of rootstocks, which lead to delayed flower initiation also enhance vegetative regeneration potential (1, 2). It was therefore decided to examine the flowering propensity of material used for cuttings to learn the extent of this relationship.

Material and Methods

In Spring 1955 yearling shoots of the apple rootstock Crab C arising from sphaeroblasts (4) and from normal buds were grafted on the dwarfing rootstocks M.VIII and M.IX. The maiden trees were of similar size but in the second year the ' sphaeroblast trees ' on M.VIII made 44%, and those on M.IX 47%, more shoot growth than the others. They were transplanted as 2-year-olds and left unpruned. Two years later when the trees came into bearing those of sphaeroblast origin bore far less fruit than the others. The following year all the blossom trusses were counted, noting the presence of trusses at the tips of lateral shoots at the top and bottom of each tree. The trees were then lifted and sawn through at their unions and the trunk and branch system weighed (Table I). There were more flower trusses on the normal trees, both actually and per unit weight of tree, than on the ' sphaeroblast trees '. There was also a marked difference in the flowering of apical and basal branch leaders, the ' sphaeroblast trees ' flowering relatively less in the lower part of the tree.

TABLE I

AMOUNT AND DISTRIBUTION OF FLOWER TRUSSES (5-YEAR-OLD TREES OF CRAB C)

Source of scion	Root-stock	No. of trees	Flower trusses per tree	Final wt of tree	Trusses per lb of tree	Nature of ten leader tip buds			
						Top of tree		Bottom of tree	
						Vegetative	Floral	Vegetative	Floral
Normal	M.VIII	3	183	8·0	22·9	1	9	2·7	7·3
	M.IX	3	258	9·0	28·7	0	10	0·3	9·7
Sphaero-blast	M.VIII	4	129	11·7	11·0	4·7	5·2	9	1
	M.IX	3	101	9·1	11·1	6·7	3·3	9	1

A further batch of trees was grafted in Spring 1957 with Crab C scions from four sources, a normal 15-year-old hedge, sphaeroblasts, 1-year root cuttings, and 1-year shoot cuttings. As before, the scions of adventitious origin, from sphaeroblasts or root cuttings, were much slower to flower (Table II). Flowering propensity was particularly well established in the hedge scions.

TABLE II

FLOWERING IN RELATION TO SCION SOURCE
(4-YEAR-OLD TREES OF CRAB C ON M.IX)

Source of scion	No. of trees	Flower trusses per tree	fruits per tree
Hedge	8	37	31
Shoot cutting ..	4	18	20
Sphaeroblast ..	9	2	2
Root cutting ..	6	2	2

Discussion

It is well known that non-flowering young seedlings have the highest rooting potential, and that a disinclination to flower accompanies an inclination to root. Adventitious shoots arising on plants in the mature phase regenerate more readily than normal shoots, suggesting a return to a condition reminiscent of the juvenile phase. It is now seen that adventitious origin of shoots leads to another juvenile attribute, namely a disinclination to flower.

The importance of the source of cuttings is well known (3) and now it appears also that the source of scions has a marked effect on fruiting. Neglect of scion source factors could lead to increased variation in planting material.

Summary

Scions of adventitious origin form trees that are delayed in their flowering, a characteristic associated with enhanced regeneration potential.

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THE COMPATIBILITY AND GROWTH OF PEAR SCIONS ON APPLE ROOTSTOCKS

By R. J. GARNER and CATHERINE P. NICOLL

As part of a wider enquiry into rootstock-scion interactions a range of apple rootstocks of widely differing vigour, namely the series M.I-M.XVI, Crab C and Northern Spy, was worked with three pear varieties. These were Beurré Hardy, chosen because of its wide compatibility with quince rootstocks, Fertility for its more selective compatibility, and Williams' Bon Chrétien for its relative incompatibility and habit of breaking at the union when budded on quince. Incompatibility between apple and pear was invariably pronounced, and although some interesting differences in behaviour were found, none of the combinations was of any commercial value.

Materials and methods

Fifty each of the apple and Quince A rootstocks were lined-out in the spring of 1953, and in August of the same year about 16 of each were budded with each of the three scion varieties. In early spring 1954 the rootstocks were cut down to within 5 in. of the scion-bud and all visible rootstock buds were sliced off.

Results

Bud take and maiden growth

The scion buds came through the winter very well, and not one of the 57 combinations was a complete failure. On 14th June the number making extension growth varied from 12% (Williams'/M.VII) to 100% (Fertility/M.VI, M.IX and M.XIV ; Hardy/M.II and Hardy/Crab C). The maiden heights, measured above the union in September 1954, are shown in Table I. Of the three scion

TABLE I

STAND AND GROWTH OF MAIDENS

Rootstock	Scions					
	Fertility		Hardy		Williams'	
	Maidens %	Mean ht cm	Maidens %	Mean ht cm	Maidens %	Mean ht cm
M.I	50	22	31	1	76	2
M.II	54	1	24	3	47	5
M.III ..	75	40	18	1	47	9
M.IV ..	75	6	31	2	35	12
M.V	94	40	18	4	35	5
M.VI ..	94	15	12	1	18	1
M.VII ..	56	19	nil	—	nil	—
M.VIII ..	81	24	44	13	18	4
M.IX ..	69	16	56	3	13	2
M.X ..	93	60	60	4	59	10
M.XI ..	69	25	12	11	18	6
M.XII ..	56	20	35	12	25	2
M.XIII ..	56	39	12	1	35	2
M.XIV ..	81	53	31	4	12	1
M.XV ..	33	36	36	4	21	34
M.XVI ..	81	66	69	17	71	12
Crab C ..	81	38	100	5	62	6
N. Spy ..	83	45	nil	—	18	3
Means ..	71	31·4	36	4·8	38	6·4
Quince A ..	94	104	100	87	94	103

Fig. 1

Three-year unpruned trees of Fertility pear on the apple rootstock M.XVI (left), and on Quince A (right). Note swelling at the union and coarse roots of the trees on M.XVI

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varieties, Fertility was much the most successful, with a mean stand of some 70% and a mean height of 30 cm, compared with stands of under 40% and mean heights of 5 and 6 cm for Hardy and Williams'.

Most of the combinations made so little growth that they do not merit further consideration (Table I). All the trees on Quince A, however, exceeded 30 cm in height. Of those on apple rootstocks, Hardy was the least successful with only one tree each on M.VIII and Crab C reaching 30 cm, and two each on M.XII and M.XVI, the latter having the tallest tree (70 cm). One or two Williams' grew on seven rootstocks of which M.XVI again gave the tallest individual tree (60 cm). In contrast all the Fertility combinations, except those on M.II, produced at least some maidens exceeding 30 cm.

When the combinations were arranged in order as expressed either by the stand or by the vigour of maidens produced, both very vigorous and dwarfing rootstocks were found throughout the range and there was no association between the known vigour of the rootstocks (2) and their compatibility with pear.

Sphaeroblast production

The normal method for inducing sphaeroblast development is complete disbudding, but such development is checked or halted immediately shoot growth resumes either from latent buds or from buds formed adventitiously in the sphaeroblasts. It is therefore of great interest that sphaeroblasts were observed on many of the apple rootstocks budded with pear, and particularly that there was considerable variation in production of sphaeroblasts between rootstocks and between groups of trees under the different scions.

The mean numbers of sphaeroblasts produced by rootstocks with no developed scion-bud are summarized in Table II. It will be seen that Fertility, revealed by the stand of grown maiden trees as the most compatible scion, is also associated with fewer sphaeroblasts in the rootstock, its mere presence tending to suppress their initiation. This effect was statistically significant ($P<0.05$), both when measured by sphaeroblast production and by the proportion of sphaeroblasts producing shoots.

TABLE II

RELATION OF SPHAEROBLAST PRODUCTION TO COMPATIBILITY

Scion	Maidens (percentage of budded)	Rootstocks with no scion shoots		
		Number	Sphaeroblasts (means per tree)	Sphaeroblast shoots (means per tree)
Fertility ..	71	84	0·82	0·05
Hardy	36	190	1·25	0·13
Williams' ..	38	192	1·24	0·19

Comparing rootstocks, the greatest sphaeroblast production was observed in M.XI, M.IV, M.V. and M.VI ; Northern Spy and M.XVI produced virtually none. M.XVI survived best of the rootstocks worked with pear and proved the least incompatible as is shown later. This suggests that the tendency to form sphaeroblasts may indicate the degree of stock/scion incompatibility.

Fruiting

Six of the Fertility trees on apple rootstocks fruited in their third year, one on M.XIII and five on M.XVI producing a total of some 5 lb of fruit. When fruit from the Fertility/Quince A trees was ripe, that from Fertility/M.XVI was hard and inedible. Three weeks later the fruit was ripe enough to eat but was unpalatable because of the large number of stone cells, mainly in the region of the core line.

Survival of trees

The trees were left in the nursery, unpruned, for three years, after which the survivors were lifted, weighed and transplanted. Only 15 trees had remained alive, namely 9 Fertility, 1 Hardy, and 2 Williams' all on M.XVI, and 1 Fertility and 2 Williams' on M.XIII. The Fertility/M.XVI plants were comparable in size and weight with the trees on Quince A. Five adjacent trees of these combinations are shown in Fig. 1. There was considerably more swelling above the unions with M.XVI than with Quince A, and the M.XVI roots were more coarse and less fibrous than those of Quince A.

The union of one tree of Fertility/M.XVI was dissected. It was mechanically strong, but there

were a few islands of unlignified tissue and all tissues were much distorted. The bark union was no worse than that found in many pear/quince combinations used commercially.

Only two trees on apple rootstocks survived transplanting, both on M.XVI and though these were still alive in 1960 they were making no extension growth ; 16 trees on Quince A transplanted at the same time survived and grew normally.

Discussion

All 18 apple rootstocks showed low but differing compatibility with pear scions, M.XVI being the most successful. In another experiment (unpublished) in which four apple rootstocks were budded with *Sorbus aria*, M.XVI alone proved more than fleetingly compatible and it is clear that this rootstock has a special tolerance of other species.

Of the pear scions, Fertility displayed the greatest affinity with apple ; it is perhaps significant that this variety has also proved the most successful for hybridizing with apple (3).

The limited compatibility between the two genera *Malus* and *Pyrus* is markedly influenced by variety of both rootstock and scion.

Summary

Eighteen clonal apple rootstocks were budded with three pear varieties. All combinations were incompatible in varying degree. The rootstock M.XVI was distinctly more compatible than the others, and the pear variety Fertility was comparatively tolerant of apple rootstocks. The degree of sphaeroblast production on the rootstocks was correlated with increased incompatibility.

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GRAFT INCOMPATIBILITY IN PLUMS: INTERACTIONS BETWEEN THE VARIETIES VICTORIA, PRESIDENT, AND MYROBALAN B

By BARBARA MOSSE

Top-working with the variety Victoria induced incompatibility between the normally compatible variety President (used as a stem builder) and the rootstock Myrobalan B (4), and this graft combination has since been widely used for studies on incompatibility (3, 7, 9). This type of incompatibility is unusual because the incompatible condition of the graft-union, which normally arises from direct contact between two incompatible graft components and can be overcome by the interposition of a very small intermediate, is here apparently translocated from the Victoria scion to the lower union. The small-scale nursery trials reported in this paper were undertaken to investigate the fundamental aspects of incompatibility between these three graft components.

Material and methods

Four nursery trials (I-IV) and two replicated field trials (V-VI) were involved in the investigation which extended from 1950 to 1958. The following material was used :

I Double-grafted trees (with 3 ft intermediates) of Victoria/President/Narrow-leaved Shiny Mussel.

II Trees of Victoria budded on Myrobalan B 3 ft above ground level, and ring-grafted with President bark veneers 6 in. below the bud.

III Two-scion trees on Myrobalan B rootstock. In these trees, buds of Victoria and President were inserted at the same time on opposite sides of the rootstock stem ; the buds of Victoria were $1\frac{1}{2}$ in. higher than those of President.

IV Double-grafted trees on Victoria and President rootstocks, obtained by layering and from hardwood cuttings of the two varieties. Both varieties as well as Myrobalan B were used in various combinations of top-scion and intermediate. Intermediates were 3 in. long.

V Double-grafted trees of Victoria/President/Myrobalan B and President/Victoria/Myrobalan B in a 10-year-old field trial (5). Additional information about the combination Victoria/President/Myrobalan B from two previous trials has been used in compiling Fig. 1.

VI Budded trees of Victoria and President on Myrobalan B rootstock, using buds from compatible and incompatible source trees. Single-worked trees on Myrobalan B served as the compatible source trees for both varieties. A tree of Victoria/President/Myrobalan B was used as the incompatible source of the variety Victoria, and feather shoots from the trunk of a similar tree were used as the incompatible source of the variety President.

Buds from all four sources were subsequently found to be virus infected, the Victoria with necrotic ring spot, and the President with mild line pattern. In addition, the compatible President trees carried a virus, probably sour cherry yellows, that caused severe stunting in peach seedlings.

Trees were planted in eight randomized blocks and observations extending over seven years were made.

Assessments of incompatibility were based on the structure of graft unions and the appearance of 4- and 5-year-old trees in trials I-IV. In the replicated trials (V-VI) total crop and final weight were also recorded.

Results

The combined results of trials I-V are shown in diagrammatic form in Fig. 1, the explanation of the symbols used being as follows :

Figures in brackets refer to the numbers of trees on which the observations were based.

C denotes compatible combinations.

-- — **C** trees without external symptoms of incompatibility but with regularly occurring mild defects in union structure. These defects were anatomical in nature and not related to various forms of swelling and over-growth at the union.

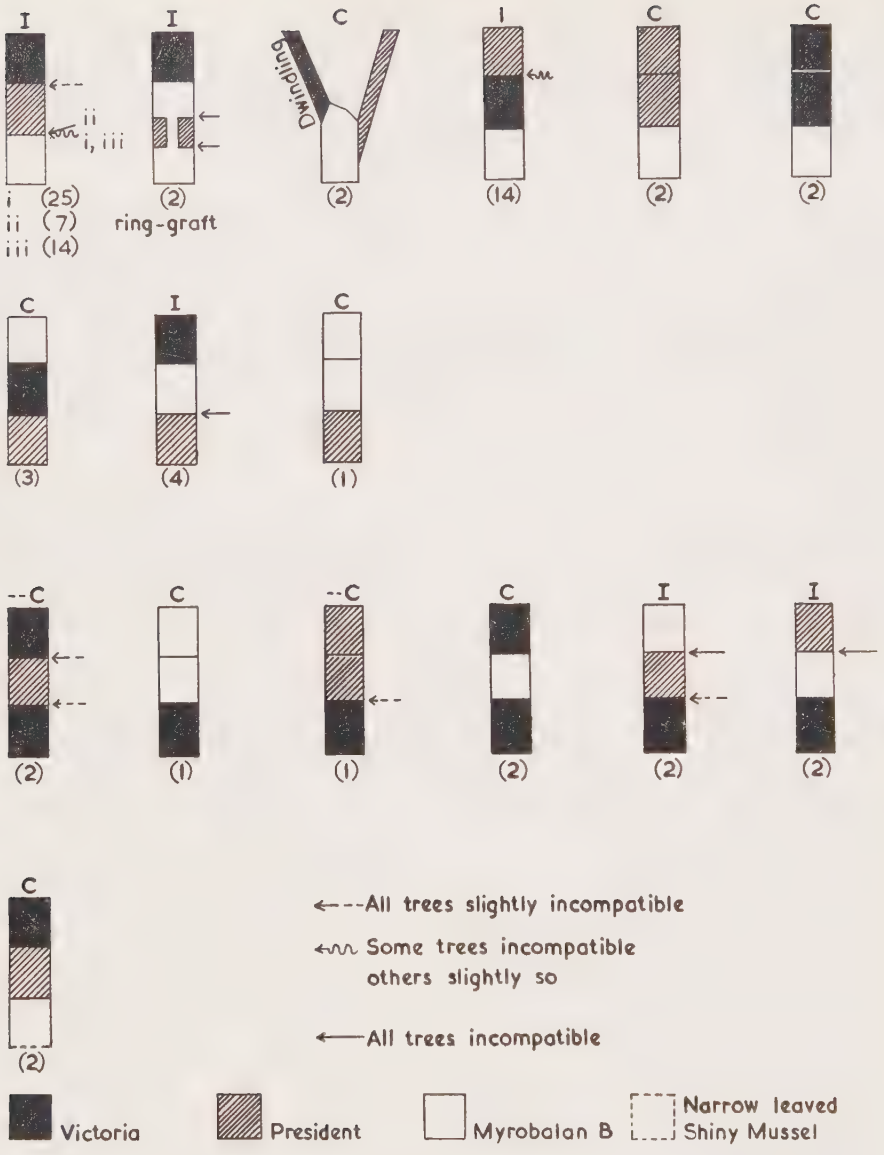

FIG. 1.

Compatibility status of composite trees containing Victoria, President, and Myrobalan B.

I denotes graft combinations in which all or some of the trees showed external symptoms of incompatibility, viz. stunted growth, sparse yellow foliage and excessive cropping, together with severe defects in union structure.

Arrows point to unions that showed anatomical symptoms of incompatibility; these were classified as slight (←— — —) or severe (←————).

←ᔓ This symbol indicates that clearly incompatible and mildly incompatible trees occurred in the same combination.

Trials I, III and V

It will be seen that varying degrees of incompatibility occurred in the two combinations Victoria/President/Myrobalan B and President/Victoria/Myrobalan B where trees were kept for ten years or longer and replication was higher. Variability is known to be one of the characteristics of incompatibility (1, 5) and it is probable, therefore, that these two graft combinations did not differ fundamentally

Fig. 2

Sectional view of President ring-graft in the rootstock stem of Myrobalan B. The incompatibility reaction is induced by the presence of the Victoria scion 6 in. above the ring-graft

from those in which all trees were found to be incompatible. Trees of Victoria/President/Myrobalan B were observed in three separate trials (4, 7, 5), only in the second of which did all the trees develop severe symptoms of incompatibility.

Three conclusions can be drawn from these results.

(1) The varieties President and Victoria are not fully compatible.

(2) In trees containing the varieties Victoria, President, and Myrobalan B, severe incompatibility develops between the two latter when they are adjacent. The relative positions and amounts of the three graft components are immaterial, and it does not matter which supplies the leaf system, provided they are in vertical sequence.

(3) The development of an incompatibility reaction is specific to Myrobalan B and does not occur with Narrow-leaved Shiny Mussel.

Trials II and III

Results of the ring-graft experiment (Trial II) show that the factors inducing incompatibility can be translocated along a mutually compatible stem piece (Fig. 2), and the behaviour of the combination Myrobalan B/President/Victoria, which also developed incompatibility symptoms, shows that this translocation was not only downwards. On the other hand no incompatibility symptoms developed in Trial III in the two Y-shaped trees with Victoria and President scions in which the Victoria branch was gradually suppressed by the more vigorously growing President, despite its advantage in being inserted slightly higher on the rootstock stem. This suggests that there is little or no lateral translocation of the causal factor, so that the distribution pattern resembles that often found with mineral deficiency symptoms where one branch or one half of a tree may be affected while the rest is normal (8).

Trial VI

It has been shown that the type of incompatibility common in citrus is induced by virus infection; any evidence of translocation of incompatibility in stone fruits would immediately suggest the possibility of a similar cause in this material. This was investigated in Trial VI which was designed to test whether buds of Victoria and President had, as a result of their growth in an incompatible tree, acquired any infection which would affect their compatibility with Myrobalan B. The mean total crop and final weight of trees raised from buds of compatible (C) and incompatible (I) source trees are given below.

	Victoria		President	
	Source I	Source C	Source I	Source C
	lb	lb	lb	lb
Mean wt of above ground portions	33·8	46·9	69·9	52·8
Mean total crop	25·6	39·8	9·2	6·6

From this it will be seen that trees of Victoria from the compatible bud source were not only larger ($P<0·05$) but carried a heavier crop ($P<0·001$) than those from the incompatible bud source. With the variety President, however, the situation was reversed and trees from the incompatible bud source were larger ($P<0·01$); their crop weights did not differ significantly. These figures suggest that with the variety Victoria the source of the buds in an incompatible tree may have had an adverse effect on their subsequent performance as scions, while the variety President may have been influenced by more severe virus infection in the compatible source trees.

None of these trees showed any symptoms of incompatibility in the structure of the bud union. It follows therefore that the incompatibility reaction between President and Myrobalan B was not due to a graft-transmissible virus complex formed in the composite tree after introduction of the variety Victoria; a more complicated explanation would be necessary, possibly involving the development of a hyper-sensitive reaction to virus in the variety President when all three graft components are present.

Discussion

Although the facts emerging from the trials that have been described are reasonably clear, their interpretation is less obvious. In a ring-grafting trial in which a translocated type of incompatibility between a peach variety and a plum rootstock was investigated (6), reciprocal grafting indicated that

one graft component might be more sensitive than the others to the factors causing incompatibility. A similar hypothesis would account for the incompatibility reactions of the variety President observed in the present experiments, a view supported by field observations on a range of top-worked trees (2) which suggested that President is more prone to incompatibility reactions than several other European plum varieties.

Possibly the most interesting observation from these trials is the absence of incompatibility in the Y-shaped trees with scions of Victoria and President on opposite sides of the rootstock. This observation is, however, based on two trees only, and requires confirmation.

Summary

Small-scale trials are described in which interactions between the plum varieties Victoria and President and the rootstock Myrobalan B were investigated. Trees were constructed containing these three graft components in different relative positions, with the following results :

(1) The varieties Victoria and President were not fully compatible.

(2) Trees containing Victoria, President, and Myrobalan B tissue in vertical sequence developed a strong incompatibility reaction between President and Myrobalan B when these were adjacent, irrespective of their relative amounts and positions in the tree. In two trees where buds of Victoria and President were inserted on opposite sides of the rootstock stem, however, no incompatibility symptoms developed.

(3) The incompatible condition was not transmissible by buds of the variety President from an incompatible tree.

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WEATHER CONDITIONS DURING 1960

By G. F. TROWELL

East Malling Research Station

The memory of the dry sunny summer and autumn of 1959 was difficult to retain during the latter half of 1960. The large quantity of rain that fell almost daily during this period was undoubtedly the most outstanding feature of the past year. Flooded, water-logged soil was far too often a common and sorry sight, greatly affecting work on the land ; lifting of potatoes was an almost impossible task. Conditions, on the other hand, during the first half of the year were somewhat the reverse, dry to mainly average weather being experienced. Although a comparatively dull year, sunshine was not as low as might have been expected, considering a six month period of almost continuous rain. Temperatures generally were above average during the first half of the year, and below average for the latter half.

The total rainfall during the year was 35·95 in., 9·22 in. above the 35-year average, and 14·53 in. more than in 1959. It was the wettest year since 1927, when 37·36 in. of rain fell. The distribution of rain during the year was divided almost into two halves, only January and May being above average during the first six months, with every month above average throughout the latter half. April was the driest month of the year, 0·72 in. falling on 9 occasions, and was once again below average. During the past 10 years rainfall during April has been below average seven times ; the average for this period is only 1·25 in. against the 35-year average of 1·90 in. Although the 2·22 in. recorded in May was above average, rain fell on only 7 days, the lowest number in any one month during the year ; June was probably the best of the summer months, having only 1·12 in. The total amount of rain recorded from January to June inclusive was 9·73 in., 1·71 in. below the 35-year average, but with rain falling on 23 days in July this deficit was almost made up by the beginning of August. August (4·31 in.) was the wettest since 1946, and September (4·11 in.), although it had fewer rainy days than August, was the wettest since 1927 (Table I). October was the wettest month of the year with 6·05 in., and the wettest since 1949 when 7·50 in. of rain fell ; then, however, only 2·86 in. had fallen in the 3 previous months, against 12·11 in. in the same period during the past year. Rainfall was also high in November with 4·91 in., the wettest day of the year occurring this month on 2nd when 1·18 in. fell. It is interesting to note that the total rain recorded between the 2nd July and 19th November was more than the total rainfall for 1959. Although drier than any of the previous five months, December and November had the highest number of days rain in any one month, 26 being recorded for each. The total rainfall for the last six months of 1960 was 26·22 in., almost the total yearly average at East Malling (rain fell on 135 days out of the 184) ; this was the largest quantity of rain recorded for this period since records began in August 1914, the previous highest being 21·86 in. in 1927. The longest wet period of the year was between 8th and 27th November ; only two days before this spell began another long wet period ended (19th October to 5th November), and a third occurred between 4th and 20th July. The driest periods were between 14th and 25th April, 29th and 10th May, and 24th May and 4th June.

Sunshine during the year amounted to 1,481·2 hours, 81·8 hours below the 25-year average, and 419·5 hours less than in 1959. Despite the past year being extremely wet the sunshine during 1960 was not as low as in 1958. Only February, June, November, and December had sunshine above average. January was the dullest month of the year with 39·5 hours' sunshine. February on the other hand was the sunniest since 1949, with March the dullest since 1947. The sunniest month of the year was June with 245·5 hours, the only summer month to have sunshine above average. Although sunshine for July was only 28·8 hours below average, it was 111·2 hours below the 1959 figure. November with 68·9 hours of sunshine was the sunniest since 1949, despite 26 wet days. The sunniest day of the year was on the 26th June when 14·8 hours of sunshine were measured. There were 78 days throughout the year when no sunshine was recorded, 21 more than in 1959.

Mean air temperatures were above average, except during July, August, September, and December; in May and June they were above those of 1959, and the 60·0° F for June was the highest since 1950. Mean maximum screen temperatures were below average during March, April, July, August, September, October, and December. Maximum temperatures in July were well below average, the 74° F recorded being the lowest maximum for this month since records began, the previous lowest being 75° F, in 1954. 63° F recorded in November was the highest maximum since 1946. Mean minimum screen temperatures were above average throughout the first six months of the year and during October and November. The 38° F recorded in July was the lowest screen minimum for this month since records began, the previous lowest being 39° F in 1939. The highest screen temperature in 1960 was 82° F on 5th June (8° lower than in 1959), and the lowest 21° F on 13th January.

Table I

SUMMARY OF METEOROLOGICAL OBSERVATIONS DURING 1960

East Malling

Month	Temperature in Screen (°F)					Number of Ground Frosts	Rainfall (in.)				Sunshine (hours)			Soil Temperature (°F)			
	Mean maximum	Mean minimum	Highest	Lowest	Mean		Total	35 years' average	Heaviest fall in a day	Number of days 0·01 in. and over	Total	Average per day	25 years' average	4 inches	8 inches	2 feet	4 feet
January	44·6	35·2	54	21	39·9	16	2·56	2·46	0·70	19	39·5	1·27	47	38·3	39·5	41·4	44·2
February	46·1	34·2	62	23	40·2	15	1·89	1·95	0·26	17	89·6	3·09	68	37·7	39·0	40·7	42·8
March	49·6	37·4	58	27	43·5	11	1·22	1·57	0·59	13	84·0	2·71	123	42·2	42·7	44·2	44·4
April	57·1	38·8	68	28	48·0	9	0·72	1·90	0·34	9	151·8	5·06	152	48·5	46·9	47·9	46·9
May	64·6	44·8	75	33	54·7	3	2·22	1·93	0·75	7	169·7	5·47	200	57·6	55·3	54·7	51·5
June	69·9	50·0	82	38	60·0	0	1·12	1·63	0·26	12	245·5	8·18	222	64·5	62·6	62·1	57·6
July	67·6	52·1	74	38	59·9	0	3·69	2·25	0·59	23	179·2	5·78	208	63·0	60·8	61·5	59·5
August	68·3	50·9	74	40	59·6	0	4·31	2·35	0·97	22	177·8	5·74	194	62·2	60·4	61·6	60·0
September	65·0	47·9	74	39	56·5	0	4·11	2·18	0·87	15	139·6	4·65	147	57·2	56·8	59·2	59·1
October	57·6	44·9	68	30	51·3	3	6·05	2·85	0·79	23	87·1	2·81	105	50·3	50·9	53·3	55·0
November	52·7	40·1	63	30	46·4	5	4·91	3·18	1·18	26	68·9	2·30	55	43·5	44·6	47·4	50·3
December	44·4	34·9	55	27	38·7	15	3·15	2·48	1·00	26	48·5	1·56	42	38·4	39·8	42·7	46·1
Totals						77	35·95	26·73		212	1,481·2		1,563				

Sub-Station, Newlands Farm, Throwley

January	42·8	34·5	52	20	38·7	19	3·56		0·96	20	38·7	1·25		38·9	39·4	41·4	44·8
February	44·1	34·3	60	27	39·2	17	2·66		0·40	17	89·4	3·08		37·2	37·7	40·3	42·9
March	48·1	37·3	56	28	42·7	10	2·12		0·71	11	87·9	2·84		41·3	41·7	43·5	43·8
April	53·8	39·3	63	32	46·6	10	0·94		0·51	10	153·0	5·10		46·7	46·3	47·4	46·2
May	62·9	45·9	72	35	54·4	5	1·90		0·55	10	186·9	6·03		56·5	55·3	52·8	49·7
June	66·8	50·1	78	39	58·5	2	1·15		0·49	9	245·1	8·17		63·3	62·1	59·4	54·7
July	66·0	51·9	70	39	59·0	1	4·01		0·68	21	169·8	5·48		61·2	60·4	60·7	57·6
August	66·7	51·3	73	43	59·0	0	4·53		1·36	19	169·9	5·48		61·0	59·8	60·7	58·4
September	62·2	48·7	71	41	55·5	0	3·35		0·58	14	137·6	4·59		57·0	57·1	59·3	58·3
October	55·6	45·7	66	34	50·7	3	8·42		1·13	27	83·9	2·71		50·9	51·4	54·2	55·3
November	50·5	40·3	60	31	45·4	10	6·33		1·04	28	61·7	2·06		45·3	45·8	49·1	51·5
December	42·9	35·0	52	28	39·0	19	4·49		0·97	24	47·7	1·54		39·4	40·3	44·1	47·7
Totals						96	43·46			210	1,471·6						

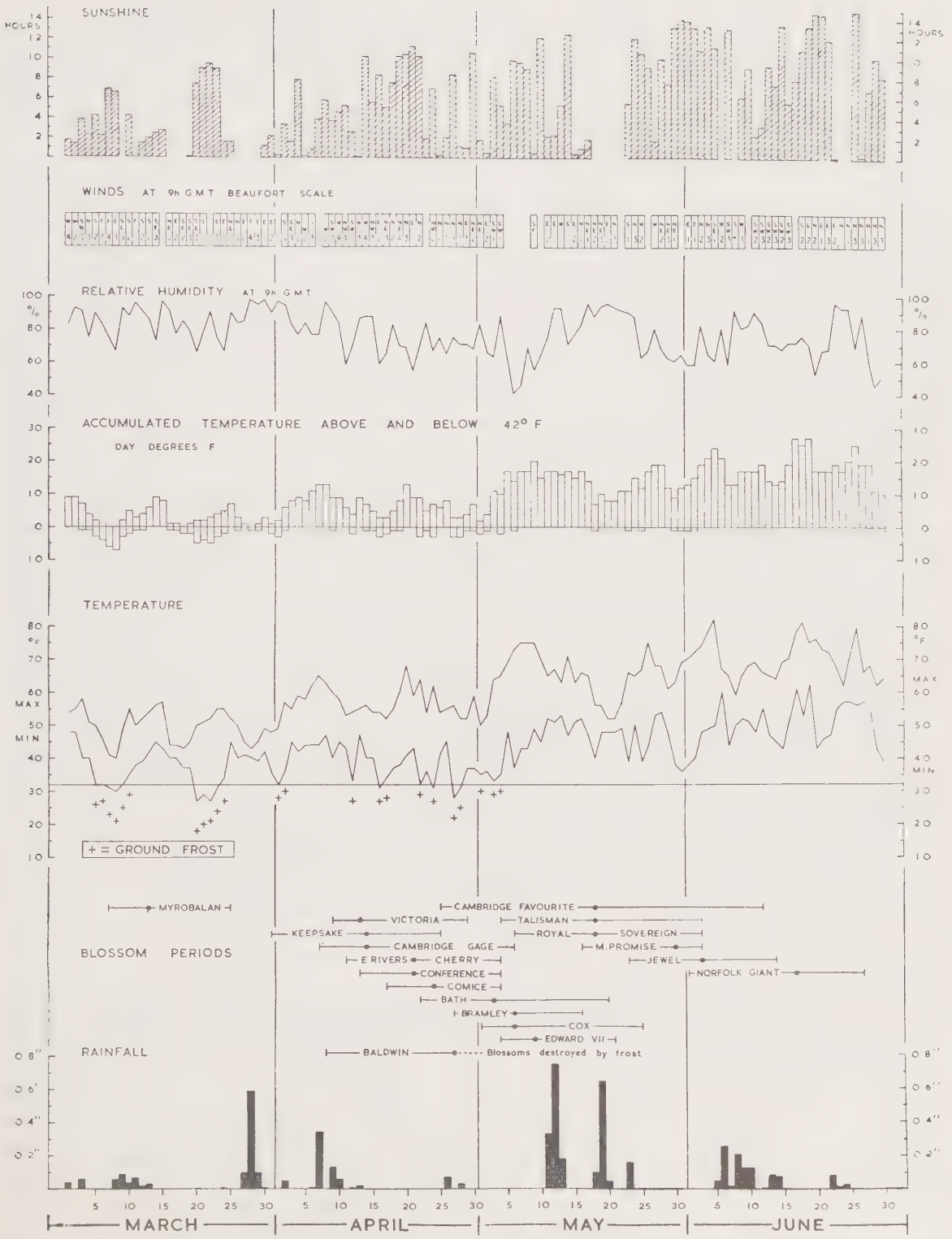

FIG. 1

Diagram showing the weather recorded during the blossoming season at East Malling in 1960

Blossoming began earlier than usual ; Myrobalan B started flowering on 7th March (Fig. 1), 11 days earlier than the average, and most later varieties flowered approximately 4–10 days early.

Cold north-easterly and strong winds of ' Force 6 ' occurred throughout much of April, making pollination conditions poor for a number of varieties (Fig. 1) ; although the north-easterly winds persisted during May, they were lighter and warmer, and conditions were then generally good for pollination. The strongest wind recorded in 1960 was 46 m.p.h. on 4th December, the only occasion when gale force winds were recorded. Strong winds of ' Force 6 ' were more frequent than in recent years, a total of 34 being recorded, the largest numbers occurring in January, April, and November.

The number of ground frosts during 1960 was only one less than in 1959 (77 compared with 78), well below the average of the past 10 years. No serious frosts occurred in May, but frosts in April caused damage to black currants and gooseberries, and to pears in some places. The last of the spring air frosts was recorded on 28th April (Fig. 1), the earliest cessation since 1947. The first autumn frost occurred on 13th October, the earliest since 1952 when it was recorded on 28th September.

Ground conditions were good for spring planting at the end of February and during March. Dry ground conditions were recorded throughout June, but wet, muddy, to ' water standing in pools ' was the experience for the rest of 1960, dry ground being recorded only 12 times during this period.

Thunderstorms were recorded 16 times over or in the neighbourhood of the Station, with the largest number occurring in July. Some brought heavy falls of rain, particularly that on 12th July when 0·47 in. of rain and hail fell in 30 min. Distant thunder was recorded on 5 other occasions.

Snow was recorded 10 times during January and February, the largest number being recorded in January. The ground was snow covered for 8 days continuously during January ; the greatest depth was 7 in. on 10th. No snow fell during the latter half of the year, but two slight sleet showers occurred in December.

Hail was recorded 3 times, during June, July, and August. Fairly heavy falls of large hail (5–8 mm) on 2 occasions (one already mentioned on 12th July), caused damage to fruitlets, which became more pronounced as the fruit grew, and was evident at the time of harvesting.

Fog was experienced 31 times, less than in recent years ; the foggiest month was December.

Newlands Farm, Throwley

Rainfall at this sub-station was 43·46 in., and, although 7·51 in. higher than at East Malling, there were fewer wet days. Dry conditions were also experienced at Throwley during April with 0·94 in., the driest month of the year. October was the wettest month with 8·42 in. of rain, with the heaviest day's rainfall of the year (1·13 in.) occurring on 8th.

Total sunshine was below that at East Malling by 9·6 hours. The sunniest day of the year was on 20th June with 15·2 hours' sunshine. No sunshine was recorded on 85 days during the year.

As in the past, mean air and maximum temperatures were above those at East Malling, while the mean minima were about the same or slightly above. The highest temperature was only 78° F on 5th and 18th June, and the lowest 20° F on 14th January.

The number of ground frosts occurring at this sub-station was considerably more than at East Malling (96 compared with 77), 2 occurring in June, and one on 1st July, when the temperature fell to 27° F. The first autumn ground frost was on 27th September.

Snow and sleet were recorded 17 times during January, February, and December. Gale force winds were experienced on 14 occasions.

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PLANT PHYSIOLOGY

TAPER AND SECONDARY THICKENING IN STEMS AND ROOTS OF THE APPLE

By R. C. KNIGHT*

The close relationship between the development in spring of buds into new shoots and the activity of the cambium in the parent stem has been observed in many plants, and its physiological associations and practical importance have been investigated (2, 3, 5, 6). The most striking feature is the downward passage of a ' wave ' of cambial activity which begins in the parent stem close to the expanding bud and progresses downwards as if a wedge of new tissue were being driven downwards between the older phloem and xylem of the parent stem. The wedges from all developing buds eventually unite to form a complete ring of new tissue which extends steadily down through the stem.

In relation to the mutual influence of stock and scion in grafted and budded plants it is obviously necessary to follow the process still further, to determine the conditions governing the development of new tissue in roots, especially in view of the nursery history of vegetatively propagated trees prior to establishment. Consequently an investigation was undertaken with a wider scope than that described in 1927 (3). The roots of vegetatively propagated fruit tree rootstocks are adventitious and arise from the lower six inches or so of the stem ; this portion of stem is buried below ground level at planting and continues its existence under unusual conditions. The establishment of a satisfactory root system on young stocks is, of course, of paramount importance in relation to the tree eventually to be built up and therefore a study has been made of the relation between the expansion of buds and the development of new tissues in the underground piece of stem and in the roots arising from it.

The development of reverse taper

The effect of disbudding the leader

Young plants of apple rootstock M.I propagated from stools were planted out and grown for two years. Thereafter in the winter of 1926-27 they were divided into two batches, each being subjected to a different pruning treatment:—

1. All shoots removed except one leader of the previous year, the buds of which were left to develop.
2. All shoots removed except one leader as in 1 above, but all the lower buds of this were removed leaving only the five uppermost ones to develop.

At intervals during the growing season sample plants were examined anatomically and observations were made on new shoot growth and leaf production, the development of new adventitious roots and the formation of new tissues in older stems and roots. In addition, similar observations were made on 3-year-old plants of M.II and M.IX apple rootstocks ; these were found to behave in the same manner as M.I, though naturally the exact date at which any given stage was reached differed with the variety, as indeed it does slightly with different trees of the same variety, and in different seasons.

The first observation was made on 4th April by which time the buds on the leaders in series 1 had expanded sufficiently to show green leaves protruding from within the bud scales, but no new xylem could be detected in any of the old stems or roots except a few elements in the ' cushion ' immediately below the bud. New young roots, however, had appeared from the stem and had reached a length of 7 cm. By 25th April the plant had grown new shoots up to 3 cm long, new roots from the underground portion of stem (which for brevity will be termed ' lower stem ' to distinguish it from the subaerial ' upper stem ') had attained a length of 20 cm, and a few new roots up to 3·5 cm long had appeared on old roots. As expected, new xylem was present in the 1-year-old stem from the tip down to a distance of 45 cm from the apex, that is, in the region where buds had begun to

* Dr. R. C. Knight died in January 1935 before he could complete the final preparation of this paper, and the manuscript has only recently become available. It is published because of its current interest. Certain additions (notably headings and the summary) and alterations have been made in the course of editing, but these have been kept to a minimum.

develop, but no new tissues were visible either in the 2-year stem, the lower stem or in old roots. A similar state of affairs existed in the partly disbudded leaders of series 2, except that xylem formation had not extended beyond about 25 cm from the apex. On 4th May, when the main new shoot was 6 cm long, carrying leaves 5 cm long, new tissues were found in the parent stem of series 1 down to a point 2 cm above ground level, but no new xylem was visible in any older roots or in the lower stem. Five days later xylem development in plants of series 2 had also reached approximately this stage. So far, growth had proceeded in series 1 and 2 according to expectation from former observations, new tissue formation in the disbudded series lagging behind that in the normal trees, and the lag continued throughout the season. Apart from this, the behaviour of the trees in the two series was similar and the description of one will suffice, with appropriate modification of dates, for both.

The downward course of the commencement of cambial activity begins to exhibit points of further interest when ground level is reached. By early May the wave of activity had travelled from the growing shoots to ground level, a distance of 60-70 cm, yet more than a month later (18th June) in some plants the lower stem showed no new xylem at all at a point 9 cm below ground level and only a few new vessels 6 cm below ground. Thus there is a very considerable retardation of the downward passage of the wave of activity in the underground piece of stem, and this occurred in all three varieties in both seasons, and continued throughout the growing period. Nothing would be gained by attempting to compare numerically the relative rates of progress of this wave in stems above and below ground because of the variation between individual plants, but the rate in the lower stem is obviously only a fraction of that in the stem above ground. The length of stem below ground is usually about 20 cm and frequently the wave does not travel quickly enough to reach the lower end of the stem by the close of the growing season. As a result, in some seasons there is no new xylem formed at the base of the lower stem and the number of annual rings there is frequently less than that at ground level.

This decreased wood formation results in the well-known ' reverse taper ' exhibited by plants growing with a piece of stem below ground. A 1-year-old rooted shoot, on its removal from the stool or layer, shows the usual uninterrupted upward taper of the stem, the diameter being greatest at the basal end. After further growth the narrowing upwards of the lower stem becomes much less marked and eventually disappears entirely, giving place to a downward taper, with the greatest diameter at ground level. This condition may be reached in one season, but it often takes two years ; even so the normal taper is much less marked after one season than at the time of planting. In later years the reversed taper becomes accentuated, the basal end showing but little increase in size from the date of planting. This is, of course, a well-known phenomenon and its immediate cause is obviously the repression of the activity of the stem cambium below ground level.

Measurements of xylem diameter of each year's growth at different levels permit a reconstruction to be made of the longitudinal section of such plants. Fig. 1A and 1B shows a diagram of a normally planted Beauty of Bath on M.V rootstock. The normal upward taper of the stock is shown in the first year's xylem, which represents the period during which the stock was growing on the mother stool. The whole of the shoot was exposed to light and air in the early part of this season, though soil was mounded around the base later in the season as is usual in propagation from stools (4). At the end of its first year the stock was detached from its parent stool and planted with about 17 cm below ground ; the second year's growth showed a distinct reverse taper in the xylem, the lower end of the stem showing no increase in size at all. In the third spring the stock was grafted and made good growth, and again the downward taper in the stock was accentuated, the process being repeated in the fourth year. The tree was then transplanted and its growth in the following season was relatively small, the downward spread of new xylem development being arrested somewhere between 10 and 12 cm below ground level. The base of this 5-year-old stock shows only three annual rings whilst just below ground level five are visible.

The effect of deep planting

It might appear that this reduction of cambial activity is the result of nutritional conditions, since the basal portion of the lower stem is below the points of origin of many of the roots, being thus off the main track of interchange of nutrients between leaves and roots, but there is evidence to show that other factors are involved. If a normally budded or grafted tree having a normal upward taper above ground level, is replanted deeply so that a considerable length of stem, instead of the usual 15–20 cm, is below ground, the same phenomenon of reverse taper appears after a year or two in the covered part of the stem above the points of insertion of the roots. This is well shown in some young trees of Bramley's Seedling which were budded on M.VI rootstocks and planted normally with 20 or 30 cm of stem below ground. After a year's growth these plants showed the normal upward taper in the scion and the reverse taper in the lower stem of the stock. They were

then replanted with about 72 cm of stem below ground, 25 cm of this being the stem of the stock and 47 cm that of the scion.

After two more years the trees were lifted and examined. In addition to the reverse taper of the stem of the stock, the length of scion stem which had been below ground for two years showed a very definite enlargement at the point representing ground level at the second planting. Fig. 1C and 1D shows the results of measuring xylem diameters at different levels on one tree of this series.

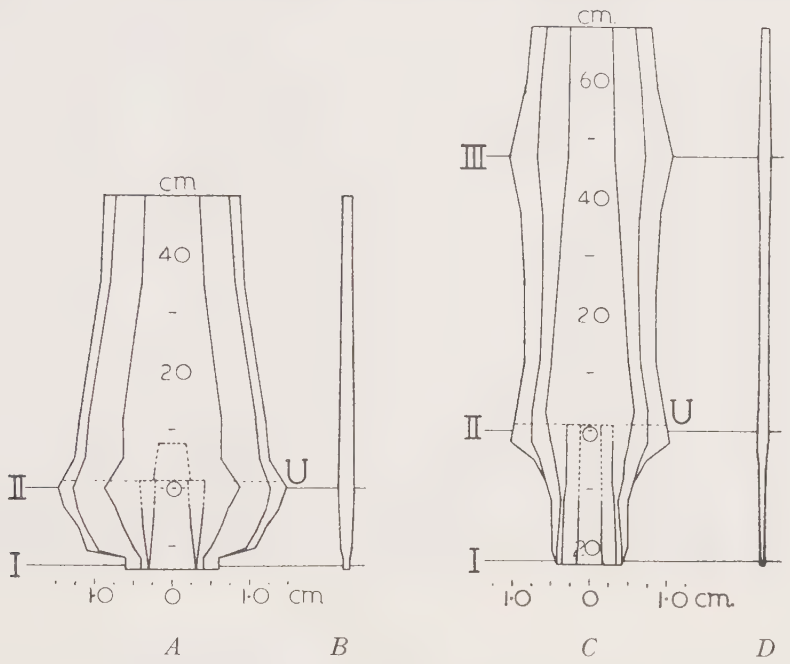

FIG. 1

Diagrammatic Section of Stems of Young Apple Trees showing the thickness of each year's wood-growth. The bark is not shown. *A* and *B* : Beauty of Bath/M.V (grafted). *C* and *D* : Bramley's Seedling/M.VI (budded). *A* and *C* : lateral scale 13·3 × longitudinal scale. *B* and *D* : lateral and longitudinal scales equal. I—approximate ground level in stoolbed, II—ground level at grafting, III—ground level after deep planting. U—approximate position of stock-scion union.

In this case the upward taper shown in the stock during its first year persisted during the second season, towards the end of which the stock was budded. In the third year the scion showed upward taper from the point of bud insertion, and the stock a downward taper. At the end of this season the tree was transplanted and the downward taper appeared in the following season in the *scion* stem below ground, the similar taper in the stock being more pronounced than hitherto. In the second year after transplanting, accentuated tapers were produced so that the scion at the new ground level became larger than at a point immediately above its insertion on the stock. Although this effect had taken two years to accomplish it should be observed that, even in the first year after transplanting, the increase in diameter of the scion was much greater at ground level than at any point below, though it was not sufficient entirely to counterbalance the previous upward taper. It is probable that the large diameter, in the final year, of the stock immediately below the point of attachment to the scion was mainly the result of the hypertrophy which so often appears at a union. The xylem of this year extended less than 8·5 cm below the union, and here again the base of a 5-year-old stock showed only three annual rings. Some of the trees in this series by the end of the second year after replanting had produced a few small roots on the scion stem below ground, but many, including that already described, had not done so, and thus the reduction of new xylem formation is not necessarily associated with parts of underground stems below the points of origin of roots.

Trunk taper in older trees

The appearance of reverse taper in stems buried below ground led to a further examination of the structure of leafless stems above ground. Swarbrick (5) observed that in the autumn, cambial activity

ceased in 1-year-old stems a month earlier than in 4-year-old branches of the same tree. In a 1-year-old tree the portion of the stem which is later to become the trunk shows a progressively smaller diameter from the base upwards, apart from irregularities due to leaf- and bud-bases. If the cambium were equally active each season over the whole of this stem the normal upward taper of the trunk would be maintained. There is, however, some evidence from annual records of trunk girths that the position of minimum diameter tends to move downwards on the main stem.* Girth measurements taken annually at different levels on the main stem show that in the early years the minimum figure is recorded close to the point of insertion of the lowest branch, but in later years the minimum girth is found to be several centimeters lower down. Since new wood formation begins at higher levels earlier than at lower levels, the result just described would only be expected if activity at lower levels did not persist correspondingly longer than activity higher up. Some measurements were made to investigate this, using stems of 14-year-old Worcester Pearmain on a series of vegetatively raised stocks. The trunks were cut transversely with a fine-toothed circular saw and the diameter of the annual rings measured. [This method had been shown to give results very similar to those obtained by a more laborious planimetering method.] The trunks were approximately 70 cm long and in a preliminary trial cross cuts were made at three points respectively 15, 30 and 45 cm below the lowest branch, thus avoiding the regions where the diameter was very much influenced by hypertrophy at the union and by branches emerging obliquely. [This investigation showed that there was very little change from the original upward taper of the stem.]

In consequence of this, other trunks were examined in more detail, transverse sections being cut at intervals of 3 or 4 cm beginning just below the junction with the lowest branch. The results showed that there is only a very slight tendency for the taper of the stem to alter (see Table I). The position of minimum diameter, which is at first near to or at the apex, certainly alters and may be as much as 20 cm below the branches in some years. The change, however, is not necessarily a regular one, and in a single season the position of minimum diameter may move 15 cm down the stem and in subsequent seasons is found to have moved several centimetres up again. Although the differences between diameters at different levels are small, the irregularities which have been observed are apparently not due to defects in the method of measurement, since in any one year all the stems examined show similar features, which are therefore probably associated with growing conditions.

TABLE I

MEAN DIAMETERS (CM) OF ANNUAL RINGS AT DIFFERENT LEVELS IN THE UPPER PART OF A STEM. WORCESTER PEARMAIN ON M.XIII

Ring	Distance in cm below lowest branch						
	5	8	11	14	17	20	23
1919*	*0·61*	*0·61*	0·65	0·69	0·68	0·70	**0·72**
1920*	1·16	*1·12*	1·17	1·22	1·24	**1·28**	1·26
1921*	1·72	*1·65*	1·71	1·70	1·77	1·78	**1·79**
1922	2·49	2·50	**2·52**	2·48	2·48	*2·47*	2·49
1923	3·44	**3·83**	3·35	3·17	3·20	*3·16*	3·18
1924	4·55	**4·94**	4·56	4·29	4·29	*4·28*	4·34
1925	5·46	**5·81**	5·56	5·28	*5·26*	5·27	5·28
1926	6·36	**6·61**	6·41	6·16	*6·12*	6·13	6·19
1927	7·37	**7·56**	7·38	7·18	*7·17*	*7·17*	7·21
1928	8·08	**8·23**	8·13	7·93	*7·92*	7·92	7·94
1929	8·91	**9·08**	8·99	8·82	8·80	*8·79*	8·80
1930	9·65	**9·76**	9·69	9·55	9·54	*9·52*	9·54
1931	10·49	**10·60**	10·53	10·36	10·33	*10·28*	10·34
1932	**11·18**	11·16	11·10	10·93	10·95	*10·92*	10·94

* Owing to the small diameters and to the influence of leaf- and bud-traces on the original 1-year-old stem, the significance of the figures for the first three years is doubtful. Minima are in italics and maxima in bold type.

The main facts which emerge from the examination of these trunks is that, in accordance with deduction from Swarbrick's observation referred to above, there is no great change in the taper of these main stems above ground, and that the phenomena already described for buried portions of stems are associated with the conditions under which these exist.

* This observation, as yet unpublished, was made by Mr. N. H. Grubb of this Station to whom thanks are due for permission to use it.

The onset of thickening in roots

Observations were also made upon roots to determine the relation between the time of commencement of new thickening and the slowing up of xylem formation in the underground stem from which the roots arise. Whilst there is no break in the downward progress of the initiation of new xylem formation in the stem above ground level. interruption does occur below ground. New xylem development in roots does not wait upon the activity in the lower stem, and new tissues may begin to appear at the proximal end of a root before the 'wave' of cambial activity reaches the point on the lower stem where that root arises. Thus at certain times there are regions of the lower stem showing no new xylem whilst both the stem above and the roots below are expanding, so that between the two growing regions a gap is left in which no new xylem is being formed. This gap closes as the activity of the lower stem cambium gradually extends downwards, and consequently the gap is not detected in every plant examined. The commencement of cambial activity in roots bears no relationship to their vertical distribution. The uppermost root is not, as might be expected, necessarily the first to begin to thicken, and it has been repeatedly observed that there is no regular basipetal succession in the initiation of cambial activity among adventitious roots arising from these vegetatively raised stocks. [An example is shown in Table II where the second column shows the distance of the roots below the branches and the third column shows a measure of the amount of new growth (? number of rows of cells). The most advanced thickening is found on Root 2, while Roots 1, 4 and 7 have not or only just started.]

Similarly it appears that the radial position of the root in relation to the branches does not determine in which root cambial activity first begins. Evidence of this was obtained from a series of trees from which all shoots were removed except two leading shoots of the previous year, these being on opposite sides of the main stem. The lower of the two was allowed to retain its buds and to develop lateral shoots normally, whilst the upper was disbudded except for about five of the uppermost buds. As expected, cambium development was much more extensive in the normal than in the disbudded shoots, and in May the main stem showed two crescents of new xylem, the larger on the side vertically below the normal shoot and a much smaller one below the partially disbudded shoot. Since the wave of cambial activity was always lower on one side of the main stem than on

TABLE II

RELATION OF POSITION, AGE AND SIZE OF ROOTS TO THE AMOUNT OF NEW TISSUE. TREES WITH SINGLE SIDE BRANCH (9th June)

Root no.	Point of origin (distance below branch insertion)	Approximate amount of new tissue	Age of root	Relative diameter	Angular divergence from side branch*
	cm		yrs		
1	26	0	2	1	270°
2	31	10	1	3	180°
3	35	5	1	2	30°
4	35	1	1	2	0°
5	36	5	2	4	60°
6	36	5	2	3	120°
7	42	0	2	5	30°

* Angle between origin of each root and origin of branch.

the other it might be expected that roots on the same side of the stem as the normal shoot would commence thickening earlier than those arising directly below the disbudded shoot. Actually, although the first roots to begin growth were sometimes directly below the normal branch, no definite association of this nature was observed. Roots below a normal shoot frequently remained unthickened after the commencement of cambial activity in roots on the opposite side. Similarly, in plants grown with a single side branch from the main stem, the first roots to thicken were not necessarily those immediately below the branch. In fact it has not been possible to establish any definite sequence in the order of commencement of xylem formation in these adventitious roots. Table II shows a typical example of the relation between the amount of new tissues and the age, size, and position of the roots. The amount of new tissue is of course not necessarily a criterion of the date

of commencement of new thickening, but a series of trees examined when new tissue had appeared in one root only have shown that the single plant of Table II accurately represents the circumstances. In this case, neither the highest nor the lowest root had begun to thicken, whilst others intermediately placed were active. There is no apparent relation between age and amount of new xylem ; activity is not associated with radial distribution since root No. 4, immediately below the branch has only just become active, whereas No. 2, on the opposite side of the main stem to the branch is most advanced, and Nos. 3, 5 and 6, with approximately the same amount of new tissue are not at similar angular distances from the branch. Finally, it is not necessarily the largest root which thickens first although in the whole series it appeared that activity began first in larger rather than in smaller roots irrespective of their age or radial or vertical position. It is not obvious why the cambium of a larger root should become active earlier than that of a smaller root. It may be that a root is larger than its fellows because of its association and ease of communication with a vigorous branch (1), but whereas this may result in greater total growth it does not seem sufficient to account for earlier growth.

The progress of new xylem formation in the root has been followed beyond the date of its commencement and it was found that the ' wave ' of initiation of xylem formation travels uninterruptedly from the proximal towards the distal end, so that as in the stem, increase in diameter does not begin concurrently along the whole length. Table III shows the amount of new xylem at different distances from the point of origin of each root and it is evident that considerable differences exist between different individual roots. Root M.R.6 showed less new growth on 11th June than K.R.7 showed almost a month earlier. It is also noteworthy that on 11th June when new shoots up to 24 cm long were present on the tree some roots had no new xylem at a distance of 20 cm from the parent stem. This delay is, of course, not found in the development of new rootlets, which are known to develop and extend to a greater or less degree all the year round.

TABLE III

PROGRESS IN INITIATION OF NEW XYLEM FORMATION IN ROOTS

Root No.	Date	Amount of new xylem at different distances from parent stem				
		1 cm	10 cm	20 cm	30 cm	40 cm
K.R.4	May 20	3	3	2	0	–
K.R.7	,, 20	4	1	0	0	–
K.R.8	,, 20	3	1	0	–	–
H.R.7	,, 11	2	–	0	–	–
M.R.6	June 11	3	1	0	–	–
M.R.8	,, 11	2	–	0	–	0

Summary

Observations are reported on the onset of secondary thickening on old stems and roots of apple trees.

Secondary thickening started below newly growing shoots and developed rapidly downwards until it reached ground level in May. Subsequent development was very much slower, and did not always reach the base of the stem underground. As a result of this, the normal taper towards the tip of the stem was reversed below ground level.

Partial disbudding reduced the rate at which the wave of thickening travelled down the stem and the amount of thickening.

When some trees were replanted deeply, the wave of thickening was slowed at the new ground level and a new position of reverse taper was initiated.

In a series of 14-year-old trees the position of minimum diameter on the trunk was at first 5-10 cm below the branches, and within 4 years descended to about 20 cm below the branches where it remained for the last 11 years.

New adventitious roots began to grow from the stem base shortly before bud development was apparent, and cambial activity in the old roots started as a wave proceeding from the old stem junction towards the root tips before the wave of stem activity reached the stem base. New roots also grew from the tips of the old roots before the root wave reached them.

The onset of cambial activity in the roots was not related to their depth nor to their positions relative to the branches.

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AN ARTEFACT IN A COLEOPTILE STRAIGHT GROWTH ASSAY METHOD

By H. W. B. BARLOW, C. R. HANCOCK, and H. J. LACEY

In the routine coleoptile straight growth test used in this laboratory for many years to assay natural growth promoters and inhibitors, five 1 cm sections are grown in specimen tubes $2 \times \frac{3}{8}$ in. in size (volume 4 ml), closed with waxed corks and rotated horizontally about their long axes (3, 5). The volume of solution is either 0·75 ml with chromatogram paper present, or 0·5 ml without, and in both cases during the test period of 20 hr atmospheric conditions within the tube remain suitable for growth. For longer periods of time, however, opening the tubes momentarily each day, or leaving them open all the time, was beneficial (Table I and (1)).

TABLE I

PERCENTAGE OF SECTIONS FLACCID AT THE TIME SHOWN, (*c*) IN TUBES CLOSED AS USUAL AND (*o*) OPENED MOMENTARILY EACH DAY OR OPEN ALL THE TIME

Days from start	NaIAA p.p.m.					
	0		0·1		10	
	c	*o*	*c*	*o*	*c*	*o*
2[a]	2	0	12	0	96	0
3[b]	0	0	0	0	24	0
3[a]	27	0	88	0	100	0
4[b]	0	0	44	0	82	0
6[a]	100	0	100	0	100	2
6[b]	64	0	100	0	100	0

a, *b* : In experiment (*a*) the tubes were opened momentarily each day (120 coleoptile sections per treatment), and in (*b*) left open all the time (25 sections per treatment).

It is evident that increasing concentrations of auxin accelerate the advent of flaccidity in closed tubes, but that even after 6 days in tubes aired briefly or open all the time there is little loss of turgor up to 10 p.p.m. NaIAA. At low temperatures loss of turgor is long delayed (1), and the benefit of open tubes less striking, but it becomes greater as the temperature or auxin concentration is raised, particularly at supraoptimal levels of either factor.

The evident importance of aeration when the test period is extended has led to a reconsideration, and after the experiments to be described here an explanation, of a curious effect previously reported (2) ; these experiments have also exposed an artefact in this test method which, if unrecognized, might well be misleading.

In ether extracts of fresh apple shoots or roots the glycoside phloridzin has been identified as an inhibitor of section extension causing a typical reaction by the section, the ends becoming flaccid and stained (6). If solutions of this natural inhibitor are tested a second time with fresh coleoptile sections the characteristic ' end flaccidity ' is replaced by a more general loss of turgor, extending in extreme cases over the whole section. Because this toxic effect was reduced by autoclaving the once-used solutions, and because the liquid became turbid (2), it was thought that micro-organisms were associated with this extreme form of damage to the sections. The identification of this inhibitory fraction has enabled experiments to be carried out to clarify the parts played by phloridzin itself, its breakdown products (resulting either from coleoptile or microbial enzymes), or substances produced by micro-organisms which merely use phloridzin as a substrate.

These experiments have additional interest in view of suggestions that phloridzin may be an important factor in the ' apple replant problem '—the failure of young apple trees to develop satisfactorily on soils which have already been cropped with apples (4, 7). If the coleoptile section could

be used to assay soils for materials deleterious to the growth of the apple, advances might well be made in this intractable problem. Such direct assays have not yet been tried, but some of the experiments described elsewhere (6) suggest that ' end flaccidity ' may be fairly specific to phloridzin, so that if this substance occurs in soils in sufficient quantities coleoptile sections might demonstrate its presence.

Materials and methods

Wheat coleoptile sections 1 cm in length were used throughout in small tubes as described above (also 3, 5). In some cases the tubes were not corked, but with the small volume of solution used there is no danger of its spilling during horizontal rotation, provided the tubes are carefully handled.

Flaccidity was either estimated visually on a 0-10 scale, 10 being completely flaccid and 4 the ' end flaccidity ' characteristic of phloridzin, or the lengths of the flaccid and turgid zones measured with an ocular micrometer at $\times 7{\cdot}5$.

Results

Table II shows the effect of sterilizing phloridzin solutions which have been used once in the standard test before retesting with fresh sections. The results confirm the earlier report (2) on the benefit of autoclaving once-used solutions of natural apple inhibitor, and show that filtering through a bacterial filter was equally effective.

TABLE II

FLACCIDITY ON SECOND TESTING OF SOLUTIONS AFTER INITIAL TEST WITH COLEOPTILE SECTIONS FOR 20 HOURS

Original phloridzin conc. (p.p.m.)	Untreated	Autoclaved	Filtered
0	0	0	0
200	48	7	0
400	98	15	12
600	100	30	25
800	100	30	35

Flaccidity is expressed as percentage of maximum score.

These results strongly suggest that micro-organisms are responsible for the loss of turgor of sections, and that they must themselves be present for maximum effect—breakdown products of phloridzin or coleoptile exudate might be inactivated by autoclaving, but would presumably pass through the filter. It still was not clear, however, whether prior exposure of the phloridzin solutions to coleoptile sections was necessary, either for bacterial growth or for some more direct reason, such as enzymic breakdown of phloridzin. To examine these possibilities an experiment was performed with a range of concentrations of phloridzin either alone or with juice expressed from coleoptile sections, this juice being used either directly or after boiling to inactivate the enzymes. The resulting mixtures (three for each phloridzin concentration) were then employed without further treatment, or after passing through a bacterial filter, and were then dispensed into sterile tubes and rotated for 20 hr with or without coleoptile sections in the standard fashion. (No attempt was made to sterilize the sections.)

At this stage, sections where present were removed and measured ; apart from a slight promoting effect of coleoptile juice there was no consistent effect of treatment on the growth of sections in the first period, and the average percentage inhibition for each phloridzin concentration was :

Phloridzin p.p.m. ..	0	50	100	200	400	800
Inhibition (%) ..	0	2	8	14	31	51

Characteristic end flaccidity occurred in all treatments at 400 and 800 p.p.m. phloridzin, and in some at 200 p.p.m. Fresh sections were then added to all tubes, and rotation continued for a further 20 hr. Since it is impracticable to present all the results (12 treatments for each phloridzin concentration), certain treatments have been grouped in Table III, showing conditions conducive to progressively greater contamination of the solutions with micro-organisms during the first period. The results indicate that while there is no great change in the inhibitory powers of the solutions,

flaccidity increases considerably with heavier microbial growth. There were no differences between treatments with boiled or filtered juice, suggesting that enzymes in the juice were not themselves affecting the result, and that the juice was simply providing a highly nutritive substrate for the growth of micro-organisms. Once-used solutions of higher concentrations of phloridzin in the standard test would contain juice exuded from the flaccid tips of the sections, which with the phloridzin would make up a suitable medium. Phloridzin alone is apparently not readily attacked.

It has been shown that sections in high concentrations of NaIAA tend to lose turgor after long periods in closed tubes of the small size usually used in these tests ($2 \times \frac{3}{8}$ in.), and that this condition may be avoided by leaving the tubes open (1). Flaccidity also sets in very rapidly in sections in tubes in which the oxygen concentration has been reduced below about 5%. With air in the tube initially, up to 20% carbon dioxide could accumulate from normal aerobic respiration ; concentrations of this order have very little effect in the presence of more than 5% oxygen, but they accelerate the development of flaccidity at lower oxygen levels. It has therefore been concluded that the flaccidity of the sections in the experiments considered here was brought about by micro-organisms producing a critical mixture of low oxygen and high carbon dioxide.

To test this hypothesis sections were grown in a range of phloridzin concentrations which had been maintained for a preliminary period of 20 hr on the klinostat under conditions judged to affect

TABLE III

AVERAGE PERCENTAGE INHIBITION AND AVERAGE FLACCIDITY (% OF MAXIMUM SCORE) IN COLEOPTILE SECTIONS USED FOR RETESTING PHLORIDZIN SOLUTIONS PREVIOUSLY TREATED IN VARIOUS WAYS

Original phloridzin conc. (p.p.m.)	(*a*) Inhibition				(*b*) Flaccidity			
	1	2	3	4	1	2	3	4
0	0	0	0	0	1	2	10	65
50	1	+2	+5	+7	0	5	10	82
100	1	+1	+1	+4	5	7	23	66
200	10	4	9	2	7	7	43	77
400	20	16	28	27	22	17	88	84
800	36	36	47	51	57	42	99	100

(1) No coleoptile juice added (4 treatments) ; (2) plus boiled and/or filtered juice, without sections in first period (3 treatments) ; (3) plus boiled and/or filtered juice, but with sections during first period (3 treatments) ; (4) plus unboiled, unfiltered juice, with or without sections in first period (2 treatments).

microbial activity, viz. without coleoptile juice, with autoclaved juice, or with non-sterile juice, each kept at either 5° or 20° C. All treatments were carried out in open or closed tubes. After this initial period for build-up of the contaminant, coleoptile sections were added to all tubes and rotation continued at 20° C for 40 hr, flaccidity being scored after 20 and 40 hr. The multiplicity of treatments has again led to grouping for presentation of the results in Table IV. In the first group, with closed tubes, are the plain phloridzin solutions without added coleoptile juice ; incubation at either temperature gave similar results, which have been averaged, showing the typical increase in flaccidity with increasing phloridzin concentration, with little change in the extra 20 hr period. In the next two groups, also in closed tubes, juice was added to the solutions, but in No. 2 contaminant activity was kept low by autoclaving or by keeping non-sterile solutions at 5° C ; after 20 hr flaccidity was rather less than in plain phloridzin, but in the next 20 hr it increased greatly. The third treatment, with non-sterile juice incubated at 20° C, was likely to build up high levels of contamination before testing, and even in the first 20 hr of test considerable damage was done to the sections ; after 40 hr the damage was complete. In open tubes, on the other hand, there were no differences due to preliminary treatments, and all have been averaged together in the fourth group ; there was negligible change during the extended test period, and throughout flaccidity was the characteristic type associated with what appears to be a primary phloridzin effect.

Phloridzin is broken down by micro-organisms under these conditions as it is in soil (4), but it has been shown (6) that the breakdown products are far less inhibitory than phloridzin itself, and do not bring about any general loss of turgor. Thus the more general flaccidity of sections in once-used solutions must be considered as a purely secondary effect of employing closed tubes of small volume, in which the gaseous relations are disturbed by micro-organisms ; on a suitable substrate their activity results in a reduction in the oxygen tension and an increase in carbon dioxide.

TABLE IV

FLACCIDITY (% OF MAXIMUM SCORE) OF SECTIONS AFTER 20 AND 40 HOURS, FOLLOWING PRELIMINARY TREATMENTS DESIGNED TO INFLUENCE MICROBIAL ACTIVITY IN THE SOLUTION

Tube state	Preliminary treatment	Test period (hr)	Phloridzin p.p.m.				
			0	100	200	400	800
Closed	(1) No juice, not autoclaved; both incubation temperatures	20	0	5	12	32	45
,,		40	1	5	15	37	55
,,	(2) Juice added; autoclaved, or incubated at 5° C ..	20	5	5	10	17	32
,,		40	72	72	87	62	65
,,	(3) Juice added; not autoclaved, incubated at 20° C	20	20	15	72	67	85
,,		40	100	100	100	100	100
Open	(4) All treatments averaged together	20	2	7	10	22	37
,,		40	7	12	15	25	40

Discussion

In biological assays, particularly of growth inhibitors, care must be taken that artefacts are not produced by the method employed, and the experience described in this paper, in which bacterial action in a closed tube of limited size was causing section deterioration by affecting the oxygen/carbon dioxide balance, is a warning that a secondary effect may sometimes be more important than a primary one.

Such a difficulty can be readily overcome by using open tubes, and it is likely that this procedure will soon be adopted in our standard test method. The importance of aeration in the straight growth test has, of course, been stressed long ago (8), and no modification of the method which ignored this factor would be likely to be used for long. In our own test, growth has been very satisfactory under most of the conditions encountered during several years, and only the abnormal respiration of strong microbial growth (induced by certain unusual circumstances) showed up this complication in the atmospheric situation within the usual test period. The timely recognition of this artefact cleared up what would otherwise have appeared to be an extremely puzzling attribute of phloridzin.

Summary

Phloridzin solutions which had been in contact with coleoptile sections for the standard test period caused in fresh sections a marked general flaccidity different from the kind limited to the ends. This toxicity was obviated by sterilizing the solutions before retesting, either by autoclaving or filtration; disturbance of the gaseous relationships by microbial activity in the small closed tubes used in this bioassay was found to be responsible, and with open tubes no such damage occurred. For the build-up of contamination coleoptile exudate or juice was necessary as well as phloridzin.

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FRUIT NUTRITION

A SURVEY OF THE pH OF THE SOILS OF EAST MALLING RESEARCH STATION

By G. C. WHITE

Recent surveys by Furneaux (1, 2) have shown the extent of variation in depth, texture and drainage of the soils of East Malling Research Station and the Trust Land. This variation is sufficient to account for some of the differences that have been observed in crop performance on these soils.

Within one soil series, the physical and chemical properties of the soil may differ widely due to local modifying factors, and some of these properties may be more definitely related to the variability of the crop. In particular, the availability of nutrients may depend to a large extent on soil reaction, and in fact some plants will not grow satisfactorily on soils of extreme acidity or alkalinity.

Truog (7) considers pH status to be the most important single chemical characteristic of the soil in assessing its suitability for plant growth. At East Malling, Goode (3) has already shown that past management of soil caused definite changes in soil reaction and this was associated with differences in the growth of apple trees ; furthermore, Holland (4) has recently investigated the possibilities of increasing the precision of field trials by using soil pH as an independent variate.

It was therefore felt that a detailed survey of the soil pH would be a useful addition to the soil surveys of Furneaux.

Method

The soil samples were taken between November 1959 and April 1960. At no time during this period did the soil dry out to any appreciable extent ; nevertheless, to check any seasonal trend in pH, some sites sampled early in the period were resampled in April. Extra soil samples were taken to determine the sampling error at a position and the difference in pH necessary to establish a change in pH between two positions.

Samples were taken from approximately ten positions per acre, on a 22 yard square grid whenever possible ; 4,602 positions were sampled in all. The surface soil (0-6 in.) and ' sub-soil ' (6-12 in.) were collected separately at each position, three cores taken with a screw auger within a four foot square making up each sample. The soil was put into serially numbered paper bags and details of the position, crop and weeds were recorded.

The fresh soil samples in their bags were spaced out on wire mesh trays and dried in a large forced-draught oven at 25-30° C and were subsequently stored at room temperature.

To facilitate subsampling for the determinations, the dry soil was crushed between rollers to a particle size of less than 5 mm. Owing to the presence of chalk granules in a large number of samples the conventional particle size of below 2 mm was not used since this would have exposed an unduly large surface area of chalk and might have biased the results.

Approximately 16 g of ground soil was added to 40 ml demineralized water in a 2 oz screw-topped jar. Batches of ten jars were shaken for two minutes on a reciprocating type shaker. A single determination to the nearest 0·1 unit was made on each sample with a Muirhead pH meter (battery-operated), the meter being standardized with buffer solutions of pH 4·0 and pH 9·0 before each batch. The washed electrodes were immersed three times into the suspension to free them of demineralized water and the reading was taken during the final immersion after 30 seconds. The glass electrode dipped into the sediment whilst the reference electrode capillary was slightly above, in the supernatant liquid, to minimize liquid junction potentials.

Results

The results of the pH determinations on the surface soil and ' sub-soil ' are shown on the two maps which are to the same scale as the previous soil maps (1, 2). The actual value for a position is not given but in its place a coloured dot centred on the position is used to indicate the particular 0·5 unit range into which the value fell.

The sampling error for a single position was found to be $\pm$ 0·21 and $\pm$ 0·20 for the surface and

'sub-soil' respectively and a difference of more than 0·6 units (P=0·05) between two positions indicated a change in soil reaction.

Table I shows the distribution of the pH values on a percentage basis.

TABLE I

DISTRIBUTION OF pH VALUES

pH range	Percentage distribution of pH values	
	0–6 in.	6–12 in.
4·0—4·4	0·6	0·2
4·5—4·9	3·2	1·7
5·0—5·4	6·2	4·0
5·5—5·9	13·3	8·7
6·0—6·4	19·8	17·1
6·5—6·9	20·7	22·8
7·0—7·4	19·1	21·8
7·5—7·9	13·3	17·1
8·0—8·5	3·8	6·6

There is a range of over 4 units both in the surface soil and 'sub-soil', with means of 6·6 and 6·8 respectively. The rather abrupt ending of the distribution at a pH value of 8·5 is related to the upper limit for normal calcareous soils; there is a more pronounced tail to the distribution on the acid side, although pH values for soil below 4 do not occur unless free acids are present.

There is a general tendency for the surface soil to be more acid than the 'sub-soil', the difference (0·24 units) between the means for the two depths being highly significant (P=0·001). The frequency distribution of differences at individual sites is shown in a histogram (Fig. 1) which was based on a sample of one fifth of the total sites. Differences outside the range +1·00 to −0·52 occur at less than one in twenty positions and suggest the influence of local modifying factors.

The limited amount of resampling at the end of the survey gave values which were not more widely

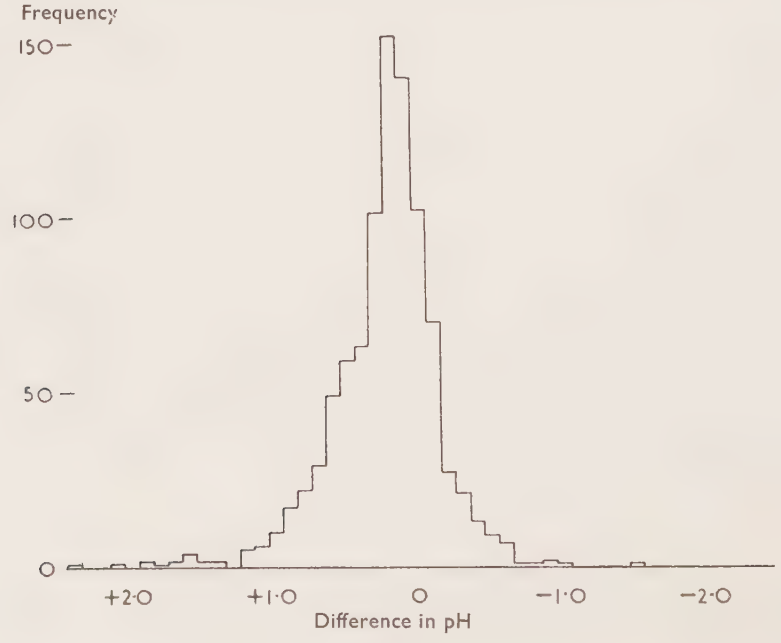

FIG. 1

Frequency distribution of differences in pH between surface soil and 'sub-soil'

A SURVEY OF THE pH OF THE SOILS OF EAST MALLING RESEARCH STATION

pH RANGE OF SURFACE SOIL: 0 - 6 in.

- 4·0 – 4·4
- 4·5 – 4·9
- 5·0 5·4
- 5·5 5·9
- 6·0 – 6·4
- 6·5 – 6·9
- 7·0 – 7·4
- 7·5 . 7·9
- 8·0 – 8·5

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divergent from the original values than would be expected from the sampling error ; there was thus no evidence of a seasonal effect within the sampling period.

Outstanding features of the survey

Detailed studies of relationships between the soil pH and soil series, topography, soil management and crop performance have not yet been completed. However, certain notable features are presented in this paper.

Acid areas.—Extreme acidity in normal soils is due to a marked depletion of the basic constituents. This may be the result of natural leaching of poorly buffered sands or may be due to the continued influence of certain additives such as sulphate of ammonia and sulphur.

Perhaps the most outstanding area is the twenty acres comprising Larkfield Plantation and part of P3, where a very large proportion of the values fall in the extremely acid categories. The light sandy soils situated over the Folkestone Beds and Sandgate Beds naturally tend to be acid. Nevertheless the soil reaction would appear to have been still further lowered by fertilizers. The soils on the rest of the Folkestone and Sandgate Beds have not reached such low values.

The soils situated over the Hythe Beds, although mainly derived from acid drifts would not normally be expected to be extremely acid, yet several such areas exist, notably C5, the southern end of Churchfields West, G12 and G13. Here the very low values may be attributed to the continued use of acidifying fertilizers.

Alkaline areas.—In contrast, there are a number of areas with pH values of over 8, indicating the influence of free calcium carbonate in the soil. This can arise through three distinct agencies—lime-saturated spring water, the direct influence of the calcareous bedrock under shallow soils, and applications of calcium carbonate (' liming ').

The area extending from the lake boundary of P14 to the southern boundary of P11 probably represents an example of the influence of the first two agencies. The influence of the bedrock on shallow soils probably accounts for the alkaline areas on Kiln Field, Egham and the small area on Wiseman, whilst lime applications would appear to have been responsible for the high pH on C13-15 and the area on Crabtree. Finally in the north-east corner of Ditton Rough there is an area where deposition of calcium carbonate from the nearby rock-crushing operations can possibly be held responsible for the alkalinity.

Variability.—The Deadman Wood area is conspicuous for the lack of uniformity of the soil reaction. Other areas contain a considerable range of pH values but some form of pattern is generally discernible, whereas in this area there is no pattern. This is doubtless due to disturbance of the soil and burning of the trash in the recent grubbing of the woodland. This explanation would account for similar areas adjacent to Newgates Shaw.

Discussion

Since only medium and light soils are represented on the Station, a rather narrow range of pH might normally be expected. Yet by the influence of the underlying bedrock and by man's management, not always intentional, the range has been extended, so that within this area of only 500 acres, the pH range of the soil—4·0 to 8·5—is almost identical with that for soils in general as quoted by Russell (6).

It is fortunate that almost three-quarters of the values fall in the range 5·5 to 7·5 where adverse effects of pH on plant growth are not likely to be of great importance. Outside this range direct or indirect effects of pH may be expected to influence crop behaviour.

Since the determinations were made on air-dried soils, this survey takes no account of the temporary acidification of the soil solution by carbon dioxide, which can cause an appreciable reduction in pH near roots, or of the concentration of dissolved salts in the soil solution.

Further, it must be recognized, in attempting to relate the results of this survey to crop performance, that there may be considerable small-scale variation ; Purvis and Davidson (5), for instance, found differences up to one pH unit between positions on a six-inch clod of soil and concluded, ' The soil mass usually does not have a constant reaction but is honey-combed with small zones of varying pH.'

By the use of composite samples these local variations are averaged out. It cannot be assumed, however, that the soil between two positions having pH values of, say, 6·0 and 6·9 will necessarily show a steady pH gradient. Each determination gains support from neighbouring points, and the survey therefore gives an overall picture of general pH gradients.

In this survey only the top 12 in. of the soil profile was examined. A large proportion of the absorbing root system is normally found in this zone so that its characteristics are likely to have a

considerable influence on plant growth. Samples taken from the manurial trial on Plot C2 in 1958 to a depth of 2 ft (Table II) indicate that, although the influence of acidifying fertilizers is very marked in the top 12 in., the lower depths are less affected. It is possible that plants growing in such a soil will, by their accommodation, obtain a more balanced mode of nutrition.

TABLE II

SOIL pH AT VARIOUS DEPTHS FROM MANURIAL TRIAL

Treatment	Means of 32 plots, each represented by a composite sample			
	0–6 in.	6–12 in.	12–18 in.	18–24 in.
With added nitrogen	4·77	5·59	6·11	6·31
Without added nitrogen	6·30	6·68	6·85	6·93

Now that the extent of the various areas of differing pH has been established, it should not be difficult by differential liming to correct extreme acidity, especially as the important differences are probably in the top 12 inches. On the more alkaline regions, especially where the soil is shallow, there is little chance of achieving any marked reduction in alkalinity.

Some general conclusions can be drawn regarding other soil properties, especially those, such as the availability of certain nutrients, likely to be linked with soil pH as indicated by Truog (7), but these generalizations cannot take the place of actual field determinations. Information on at least the 'available' potassium and magnesium will be obtained from the soil samples collected in the survey and the results will be given in a future paper.

Acknowledgements

The very considerable sampling programme was carried out with the assistance of Messrs. K. V. Kimber and M. E. Burley, who also did most of the grinding of the samples and the actual determinations. Messrs. K. J. Hyrycz, J. W. Aylott and B. A. Turfrey also gave some assistance in collecting the samples and Miss A. D. L. Cheeseman carried out some of the determinations.

Summary

A detailed pH survey of the soils of East Malling Research Station and of the Trust Land has been carried out. Determinations were made at 22-yard intervals on the surface soil (0-6 in.) and 'sub-soil' (6-12 in.). The results are presented in the form of two coloured maps showing the distribution of the soil reaction in 0·5 unit ranges.

The range of values obtained (4·0 to 8·5) was considerable, but 75% fell in the range pH 5·5 to 7·5.

Comments are made on areas of extreme acidity, alkalinity and variability and the results are discussed in relation to pertinent factors.

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A SURVEY OF THE pH OF THE SOILS OF EAST MALLING RESEARCH STATION

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THE EFFECT OF EPSOM SALT ON THE INCIDENCE OF POWDERY MILDEW ON POTTED APPLE ROOTSTOCKS

By ELSIE M. FORD and E. L. FRICK

In experiments on a stoolbed of MM.102 apple rootstocks (Ford, 1958), fortnightly sprayings with a solution of 2% Epsom salt ($MgSO_4 \cdot 7H_2O$), containing 0·01% di-octyl sodium sulphosuccinate (Aerosol OT) as the wetting agent, prevented the appearance of symptoms of magnesium deficiency ; a lower level of infection by mildew (*Podosphaera leucotricha* (Ell. and Ev.) Salm.) was also observed on these plants than on those deficient in magnesium (Roach, 1955). These observations prompted the following questions : (1) do sprays of Epsom salt solution act as a fungicide against mildew, and (2) are magnesium-deficient plants more susceptible to this disease ?

Experiments were therefore carried out in 1959 and 1960 in which apple rootstocks, grown at two levels of magnesium nutrition, were given appropriate spray treatments, then inoculated with mildew spores, and the resulting number of lesions recorded.

1959 Experiment

Material and method

One-year layers of MM.102 rootstock selected for uniformity during autumn 1958 from the experimental nursery stoolbed (Ford, 1958) were bedded-in for use in the following season. Plants for Treatments 1, 2 and 3 (Table I) were taken from the stoolbed plots receiving Epsom salt both as soil dressings and as foliar sprays, and plants for all other treatments from untreated plots known to be deficient in magnesium.

Early in 1959, the plants were potted in 4 in. ' Long Tom ' pots in soil from which they had been harvested and to which peat and a general fertilizer had been added ; additional Epsom salt was mixed with the soil of Treatments 1, 2 and 3. All the pots were then bedded in ashes in the open. In mid-May each shoot was cut back to 3 or 4 buds to promote young shoots. Because growth was poor (probably due partly to drought and partly to unsuitable soil), a balanced nutrient solution was given daily from early July onwards, the magnesium being omitted from appropriate treatments (Table I).

Sprays were applied to Treatments 2, 3, 5, 6, 7 and 8 with a hand-sprayer, all leaves being wetted completely but with little run-off. Weekly applications in treatments 2, 3, 6 and 8 were begun in mid-June and were continued up to the day before mildew inoculation ; this last application coincided with the single application in Treatments 5 and 7.

To minimize natural mildew infection, 1% lime-sulphur (with nicotine to control aphis) was applied to all plants a fortnight prior to inoculation.

At a suitable, pre-determined stage in their growth (21st July), 10 plants, reduced to 2 shoots per plant, were selected for uniformity from the 15 plants per treatment and artificially inoculated with mildew spores, using the settling-tower technique of Kirby and Frick (1960). After 9 days the number of mildew lesions per leaf on leaves 3, 4 and 5 per shoot was recorded, leaf 4 being the youngest fully expanded leaf at the time of inoculation.

Finally all the leaves from shoots used in the mildew inoculation test were cleaned (Mason, 1953), dried at 80° C, and bulked by treatment for determination of magnesium (Allen, 1960).

Results

Results (Table I) were complicated by the poor growth made by the plants and by the leaf scorch caused by moving the plants sprayed with Epsom salt to the hot, humid atmosphere of the greenhouse prior to mildew inoculation. Apart from this damage, no other leaf scorch due to differential magnesium nutrition was apparent.

Leaf magnesium content.—Although, owing to the bulking of samples, the data expressing the magnesium content of leaves as percentage of the dry weight were not suitable for statistical treatment, there are obvious differences. In plants grown in the low magnesium soil the leaf magnesium concentration was low (0·16–0·17%) in those that had received either no sprays or sprays of wetting agent only, whereas applications of Epsom salt increased the concentration to high values. In contrast, leaves of plants grown with adequate magnesium in the soil contained a normal amount of magnesium (0·21% dry weight), and this also was increased to a high level by weekly applications.

TABLE I

MAGNESIUM CONTENT OF LEAVES AND MEAN NUMBER OF MILDEW LESIONS PER LEAF—1959 EXPERIMENT

Treatment			Mg content of leaves (% dry wt)	Lesions per leaf
Soil Mg	Foliar sprays			
	Wetting agent	Epsom salt + wetting agent		
1. Adequate	—	—	0·21	6·8
2. ,,	Weekly	—	0·20	6·3
3. ,,	—	Weekly	0·43	3·2
4. Low ..	—	—	0·16	10·5
5. ,, ..	1 Spray	—	0·17	7·0
6. ,, ..	Weekly	—	0·17	6·7
7. ,, ..	—	1 Spray	0·39	3·2
8. ,, ..	—	Weekly	0·43	3·7

Mildew lesions.—On plants deficient in magnesium the incidence of mildew was reduced ($P<0·001$) where wetting agent sprays were applied weekly or once only (Treatments 5 and 6), as compared with unsprayed plants (Treatment 4). However, applications of wetting agent only did not reduce the incidence on plants grown with adequate magnesium in the soil (Treatments 1 *v.* 2).

The lowest numbers of lesions per leaf occurred on plants that had received sprays of Epsom salt/wetting agent. Thus, on plants grown in soil low in magnesium and sprayed either weekly or once (Treatments 7 and 8) fewer lesions per leaf appeared ($P<0·001$) than on corresponding plants sprayed with wetting agent alone (Treatments 5 and 6). A similar effect ($P<0·01$) occurred with plants growing in soil to which magnesium had been added (Treatments 2 and 3).

On plants grown in soil low in magnesium the single Epsom salt/wetting agent application just before mildew inoculation (Treatment 7) was as effective in controlling the disease as were the weekly Epsom salt applications (Treatment 8).

When plants were not sprayed, more lesions per leaf ($P<0·001$) occurred on those grown in deficient soil than on those in soil to which Epsom salt had been added (Treatments 4 and 1 respectively).

1960 Experiment

Material and method

Plants were selected as in the previous year, but bedded in sphagnum in cold store at 37° F until the following spring. In an attempt to induce better growth than in 1959, plants were grown in washed Bedfordshire sand instead of soil and nutrient solutions were given daily, magnesium being omitted from Treatments 2–6 inclusive (Table II).

Treatments differed from those of 1959 in that weekly sprayings were (*a*) confined to plants receiving no magnesium in the nutrient solution, and (*b*) discontinued one week before mildew inoculation to separate the effect of the spray applied immediately prior to mildew inoculation from that of the preceding sprays.

The general procedure was similar to that of 1959, except that 16 plants were finally selected for mildew inoculation from the 30 plants used for each treatment, and that the aggregate leaves of each selected plant were analysed for magnesium content.

Results

Growth was good and very uniform and at the time of mildew inoculation the young shoots were still growing vigorously. No foliar symptoms of magnesium deficiency were apparent on plants receiving magnesium through their roots (Treatment 1) or on those sprayed weekly with Epsom salt/wetting agent solution (Treatment 6). Under all other treatments, symptoms, in the form of interveinal scorching of leaves, occurred on approximately the lower third of each shoot.

Leaf magnesium content.—The leaf magnesium concentration of plants grown with a complete nutrient solution was normal (0·23% dry weight) whereas that of plants grown with a magnesium deficient solution and receiving no foliar application of magnesium was exceedingly low (0·05% dry weight). A single application of Epsom salt/wetting agent spray increased the magnesium concen-

TABLE II

MAGNESIUM CONTENT OF LEAVES AND MEAN NUMBER OF MILDEW LESIONS PER LEAF—1960 EXPERIMENT

Treatment			Mg content of leaves (% dry wt)	Lesions per leaf
Mg supplied to roots	Foliar sprays			
	Wetting agent	Epsom salt + wetting agent		
1. Adequate*	—	—	0·23	7·01
2. None ..	—	—	0·05	7·28
3. ,, ..	1 Spray	—	0·05	4·63
4. ,, ..	Weekly	—	0·06	6·60
5. ,, ..	—	1 spray	0·15	2·27
6. ,, ..	—	Weekly	0·37	5·65

* Nutrient solution contained 48 p.p.m. magnesium supplied as magnesium sulphate.

tration to 0·15%, which was still below normal, while weekly applications raised it to a high level (0·37% dry weight). All differences except those between Treatments 2, 3 and 4 are significant at $P<0·001$.

Mildew lesions.—A single application of wetting agent only prior to mildew inoculation (Treatment 3) substantially reduced the number of lesions produced ($P<0·001$), and this treatment was more effective than a similar application made weekly up to one week before inoculation.

Weekly applications of Epsom salt/wetting agent sprays up to one week before inoculation (Treatment 6) led to a lower incidence of mildew ($P<0·05$) compared with unsprayed deficient plants (Treatment 2). The lowest incidence of mildew, however, resulted from a single application of Epsom salt/wetting agent spray one day prior to inoculation (Treatment 5). The improvement over the effect obtained with the corresponding single application of wetting agent only (Treatment 3) was significant at $P<0·01$, and over that with the weekly applications of Epsom salt/wetting agent spray (Treatment 6) at $P<0·001$.

The unsprayed plants of contrasting magnesium status (Treatments 1 and 2) showed no difference in mildew infection, although in Treatment 1 the supply of magnesium to the roots had raised the level of magnesium in the leaves to normal.

Discussion

In the 1959 experiment a single application of the Epsom salt/wetting agent spray immediately before plants were exposed to mildew spores was as effective as weekly applications in controlling mildew infection ; as the last of these weekly applications was made on the same day as the single application immediately prior to mildew inoculation, its effect may, however, have masked any effect of the preceding sprays. In 1960, the weekly applications ended one week before mildew inoculation and plants receiving them showed again a reduction in the incidence of disease, when compared with unsprayed plants ; however, far greater control resulted from a single Epsom salt/wetting agent application immediately before mildew inoculation, and it may therefore be concluded that this spray was acting as a fungicide. On plants with a low magnesium content, some control was also provided by the wetting agent alone when applied on the day before inoculation. Yarwood (1951) found in laboratory experiments that 0·5% di-octyl sodium sulphosuccinate was required to give 95% therapeutic control of bean powdery mildew.

Since weekly Epsom salt/wetting agent sprays had some effect in preventing mildew infection as well as raising the leaf magnesium content, it is pertinent to ask whether the lower disease incidence resulted only from spray residue on the leaves, or whether the resulting ' healthier ' plants—in the sense that they were not magnesium deficient—were more resistant to mildew attack. Plants receiving a low supply of magnesium in 1959 and none in 1960 were compared in both years with plants receiving adequate magnesium, no sprays being applied. In the former year when all plants were stunted more lesions occurred on the plants with a border-line magnesium deficiency than on those with adequate magnesium, but in 1960 when good growth was obtained no such difference resulted between those not receiving magnesium and those with an adequate supply. There may be many possible explanations of this discrepancy and there is need for further investigation.

The evidence from the 1960 experiment that severe magnesium deficiency does not increase susceptibility to mildew is supported by the absence of a consistent relationship between magnesium content and mildew infection of leaves. For example, although the magnesium concentration in leaves that had received weekly Epsom salt/wetting agent applications was high, and only a medium-low magnesium value resulted from the single application just before mildew inoculation, the former treatment was less effective than the latter in reducing mildew attack. It is certain that at the time of mildew inoculation there was a large deposit of Epsom salt on the leaf surface, due to the single spray, which could not be indicated by the leaf analyses as the leaves had been thoroughly washed. It may therefore be concluded that this spray deposit was the main factor in preventing mildew infection.

Summary

One-year layers of MM.102 rootstocks were used to investigate the possible influence of (1) foliar sprays of Epsom salt, and (2) magnesium nutrition, on the incidence of apple mildew (*Podosphaera leucotricha* (Ell. and Ev.) Salm.) following artificial inoculation.

Plants were grown in pots with either an adequate or a low level of magnesium supplied to the roots ; some of these plants were sprayed either once only or at weekly intervals with 2% Epsom salt plus 0·01% di-octyl sodium sulphosuccinate as wetting agent, or with the wetting agent alone.

Some reduction in mildew attack was obtained with sprays of wetting agent alone, but further control was achieved with Epsom salt/wetting agent sprays. The greatest control was given by a single application one day before inoculation, due apparently to the deposit of Epsom salt remaining on the leaf surface.

Evidence for an effect of magnesium nutrition on susceptibility to mildew is not conclusive. In the 1960 experiment there was no clear relationship between the magnesium content of leaves and degree of infection, suggesting that any effect of magnesium nutrition on susceptibility is of less importance in preventing infection than is the direct fungicidal effect of Epsom salt sprays.

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PLANT PATHOLOGY

EUROPEAN RUSTY MOTTLE DISEASE OF SWEET CHERRY

By A. F. POSNETTE and R. CROPLEY

The name rusty mottle was applied to a prevalent virus disease of sweet cherry trees in England (2) because of the supposed resemblance to mild rusty mottle disease in North America (7, 8). Discussion with American authorities and visual comparisons of the symptoms of these diseases in California, Oregon, Washington, British Columbia, and England have revealed more differences than similarities between the disease occurring in England and that in North America. So far as the authors have ascertained, no symptoms characteristic of the European disease have been seen in North America.

Characteristics of European rusty mottle disease

Under the climatic conditions in England, symptoms first develop on cherry leaves in July, when groups of the fine veins (tertiary and fourth order) of mature leaves become clear and then turn yellow (Fig. 1). The leaves gradually assume a dull green colour in contrast to the bright green of healthy leaves and by the end of August they have a yellowish-green appearance. Rusty red pigment develops in spots on the leaf surface during August, usually but not invariably associated with the yellow veinlets (Fig. 2) ; the amount of red colouration varies with the strain of the virus. Neither ring pattern, premature autumnal yellowing of the leaves, nor leaf-fall occurs ; the shedding of yellow-green mottled leaves with green rings in early summer, so characteristic of rusty mottle (6) and mild rusty mottle diseases in North America, does not occur.

Some commercial varieties develop slight symptoms, but many carry the virus in latent form. The rusty vein symptom has been recorded on Frogmore, Gaucher, Roundel, Van, and Bing. Mazzard F12/1 is the most sensitive variety and virus strains can readily be distinguished by the severity of symptoms produced in the year after inoculation.

Some virus strains have induced conspicuous dark red spotting and vein-banding similar to red mottle in pear (3), while others have induced mainly yellow or pale rust-coloured pigmentation. One isolate caused necrotic spots on F12/1 leaves in the absence of necrotic ring spot virus (4). Trees infected with this isolate were not protected against the shock effect produced by necrotic ring spot virus.

Attempts to find other hosts of rusty mottle were unsuccessful. Young seedlings of tobacco, cucumber and *Chenopodium amaranticolor* remained symptomless after inoculation with buffered sap from young leaves of infected F12/1 plants. Peach, morello, myrobalan, and *Prunus mahaleb* seedlings have not developed symptoms when inoculated by budding with mazzard F12/1 scions infected with rusty mottle ; the peach seedlings were tested for virus infection by budding F12/1 plants and they proved to be healthy. Scions of F12/1 infected with rusty mottle were grown on Shirofugen (*P. serrulata*) without the necrotic reaction characteristic of necrotic ring spot infection.

Effect on growth

Field experiments showed that rusty mottle virus reduced the growth of mazzard F12/1 plants by 23% (height and girth). The growth of scion varieties was less reduced but the yield of fruit of infected Napoleon and Early Rivers trees was only three-quarters that of healthy controls (4, 5). The fruit was normal in size and time of ripening.

Heat treatment

All Roundel trees examined were infected with rusty mottle virus and attempts were made to produce healthy material by heat treatment. In one experiment, for example, young trees growing in pots were maintained at 37° C. (±2) during July, and after 18 days buds from the 1-year-old wood were grafted on to healthy F12/1 plants ; each of the 21 buddings raised was still infected with rusty mottle virus. This result confirmed that rusty mottle virus is not a strain of necrotic ring spot virus which can be eliminated by such treatment (1).

Spread in orchards

In England rusty mottle virus is spread chiefly by the use of infected scionwood in propagation. This is indicated by the frequent occurrence of the virus in certain varieties, particularly Roundel and Noble, and its rarity in other varieties known to be susceptible. In one orchard containing 30-year-old trees of Early Rivers and Turkey Heart, all 43 of the tested trees of the latter variety were infected with rusty mottle but only 9 of the 37 Early Rivers trees. Reciprocal infection with ring mottle virus from the Early Rivers to the adjacent Turkey Heart trees suggested that root-grafting was responsible for the infection of 8 of these Early Rivers trees.

Discussion

The distinction now established between the English and American rusty mottle viruses raises the problem of nomenclature. Any new name now applied to the former should be abandoned if a strain relationship to the American virus were later demonstrated. Symptoms identical with those described in England have been seen in Holland, and the rusty mottle virus has probably been widely distributed in Europe by the interchange of scionwood. A more apt description than ' rusty mottle ' for the characteristic symptom on cherry has not been found, and the authors therefore propose that the prefix ' European ' should be used to distinguish the virus and the disease described above from those described in America.

Summary

The virus disease prevalent in sweet cherry trees in England was considered similar to mild rusty mottle disease in North America, but the two diseases are now regarded as distinct. Shedding of yellow leaves with ring patterns in early summer, typical of American rusty mottle, does not occur with the European form in which rust-coloured pigmentation of the leaves in late summer is characteristic. The virus is apparently not related to necrotic ring spot or other *Prunus* viruses, and it should be distinguished by the name European rusty mottle.

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Fig. 1
The vein clearing symptom produced on F12/1 in July

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FIG. 2
Rust-coloured vein-banding and yellow mottle produced on F12/1 in August and September

PATHOGENICITY TESTS WITH ISOLATES OF *PSEUDOMONAS MORS-PRUNORUM* FROM LEAF SURFACES OF SPRAYED AND UNSPRAYED CHERRY TREES

By J. E. CROSSE and N. SHANMUGANATHAN

Pseudomonas mors-prunorum occurs in abundance on the leaf surfaces of the sweet cherry and this population is the main source of infection for stems and branches during the autumn. In the following experiments the virulence of strains of this organism derived from the leaf surfaces of sprayed and unsprayed cherry trees was compared. Apart from evidence of parasitic adaptation by *Ps. mors-prunorum* to cherry, plum and apricot (1) there was little previously known about pathogenic variation within this species.

Materials and methods

Isolation of *Ps. mors-prunorum*

Cherry leaves were taken from trees in the autumn, shaken with water, and the washings plated out according to the method described elsewhere (3). Colonies of *Ps. mors-prunorum* were picked off at random and transferred to slopes of nutrient agar containing 2% glycerine.

Source of isolates

Two experiments were conducted. In the first, isolates were obtained from a plot of 5-year-old Napoleon cherry trees forming part of a spray experiment. In October, 10 strains in each of 3 groups were isolated respectively from (a) unsprayed trees, and from trees sprayed earlier in the year with (b) streptomycin or with (c) Bordeaux mixture.

Strains for the second experiment came from another plot of 5-year-old Napoleon trees in a similar spray experiment. Two groups, each of 10 strains were collected from (a) trees which had never been sprayed and from (b) trees sprayed with streptomycin (220 i.u./ml) for three successive years preceding the year of isolation. Platings for Group 2 were made on media containing 4 or 8 p.p.m. of streptomycin sulphate. As most strains are inhibited by these concentrations, Group 2 were above average in resistance to the antibiotic.

Preparation of inocula

After 24 hours' growth, bacteria from slopes of nutrient agar plus 2% glycerine were suspended in sterile distilled water. All inocula were adjusted to approximately 5×10^7 bacterial cells per ml, in Experiment 1 by reference to a calibration curve relating viable numbers to optical density, and in Experiment 2 by matching with a barium sulphate standard.

Determination of pathogenicity

Inoculations were made in the winter through V-shaped cuts into 2- and 3-year-old wood of 6-year-old Napoleon trees low-worked on F12/1 rootstocks; the cuts were bound immediately with sterile rubber crepe or with polythene tape. Different sets of trees were used in Experiments 1 and 2, but the trees within each set were propagated from the same clonal source in the same nursery and planted out at the same time. Each strain was inoculated once on each tree at a site selected at random, and replicated on six trees in Experiment 1 and on ten trees in Experiment 2. Ten control wounds on each tree, corresponding to a group of strains, were included in the randomization. The strains were inoculated one at a time to all trees, and each experiment was completed within two days. The proportions of 2-year-old and 3-year-old wood used for inoculations were approximately the same on all trees. The lengths of the lesions developed by the following April were taken as a measure of virulence.

Results

The results were examined by an analysis of variance, using the untransformed data. The differences between strains and groups referred to below were highly significant ($P < 0.001$) unless otherwise stated.

Except on one tree, all control wounds in Experiment 1 became naturally infected, the mean lesion length being 3·6 cm ; this was less than the means for each of the three groups of inoculations. There were differences between strains from trees sprayed with streptomycin or with Bordeaux mixture, but not between those from unsprayed trees. The means for the former two groups did not differ, but both were higher than the mean for strains from unsprayed trees. When individual trees were compared, the mean lesion lengths for all inoculations were less on trees 1 and 2 than on the other trees, the differences being very highly significant ($P<0·001$) (Table II).

TABLE I

LENGTH OF BRANCH LESIONS (CM) RESULTING FROM INOCULATION OF STRAINS OF *PSEUDOMONAS MORS-PRUNORUM* ISOLATED FROM THE SURFACES OF CHERRY LEAVES
(mean of 6 replicates)

Strain groups and tree-source	Strain No.										Group means
	1	2	3	4	5	6	7	8	9	10	
Uninoculated controls	3·3	3·0	4·3	2·5	3·0	3·9	3·7	3·3	4·2	4·2	3·6
a. Unsprayed ..	5·5	4·7	5·0	5·5	6·0	3·8	4·2	4·0	4·5	4·3	4·6
b. Streptomycin ..	7·4	8·8	8·5	5·2	5·8	11·3	4·3	4·6	5·4	3·2	6·4
c. Bordeaux mixture	4·4	4·1	4·7	7·6	4·2	5·6	4·8	12·0	5·6	4·6	5·8

TABLE II

MEAN LENGTHS (CM) OF BRANCH LESIONS ON INDIVIDUAL TREES RESULTING FROM INOCULATION WITH 30 DIFFERENT STRAINS OF *PS. MORS-PRUNORUM* ON EACH TREE

	Tree No.					
	1	2	3	4	5	6
Mean lesion length (cm)	3·7	4·3	5·3	5·7	5·7	5·9

Non-significant differences are bracketed ($P<0·001$)

TABLE III

LENGTH OF BRANCH LESIONS (CM) RESULTING FROM INOCULATION OF STRAINS OF *PS. MORS-PRUNORUM* ISOLATED FROM THE SURFACES OF CHERRY LEAVES
(Mean of 10 replicates)

Strain groups and tree-source	Strain No.										Group means
	1	2	3	4	5	6	7	8	9	10	
a. Unsprayed ..	10·2	8·8	10·2	4·9	9·6	11·7	10·8	11·7	8·8	11·2	9·8
b. Streptomycin ..	4·5	10·8	2·3	8·7	3·4	4·6	4·6	9·8	10·4	9·2	6·7

Infection of control wounds was negligible in Experiment 2. As a group the strains from unsprayed trees were more virulent than the group from trees treated with streptomycin ($P<0·05$) and within both groups there were differences between strains (Table III). No differences between trees were discerned in this experiment.

Discussion

Most of the isolates of *Ps. mors-prunorum* from the leaf surfaces of sprayed and unsprayed cherry trees were pathogenic when inoculated into cherry branches during the winter. In the first experiment the results were complicated by the high incidence of natural infection in the control wounds ; thus of the 30 strains, 8 which gave means no greater than the highest of the control series (4·3 cm) were

of doubtful pathogenicity. No such complication arose in the second experiment where all strains were clearly pathogenic, although differing considerably in virulence.

The strains from sprayed trees in the first experiment were more virulent as a group than those from unsprayed trees, but with only 10 strains in each group it is doubtful whether any significance can be attached to this. Neither group from sprayed trees was homogeneous within itself and the high group means were found to be due to the influence of relatively few strains, the selection of which may have been a matter of chance. Similarly in the second experiment there was no real evidence that virulence was in any way related to the use of streptomycin either as a spray or included in the isolation medium. Hence, although spraying is known to kill many of the bacteria on the leaf surfaces (2), there was nothing in these experiments to suggest that it affects the virulence of the survivors.

The behaviour of individual trees (Table II) indicates that trees of the same age, variety and rootstock, and, so far as is known, the same nursery history, may not show the same resistance to the disease when planted out in an orchard. Field observations of natural infections over many years support this conclusion. The reasons for these differences are unknown, although obviously a site or soil effect must be amongst the possibilities considered. Whatever the reasons, there is now additional evidence that a factor or factors other than variety and rootstock may determine the resistance to bacterial canker of orchard cherry trees.

Summary

Most of the isolates of *Pseudomonas mors-prunorum* from the surfaces of unsprayed cherry trees and from cherry trees sprayed with streptomycin or Bordeaux mixture were pathogenic when inoculated to branches in the winter, but they differed in virulence. There was no clear evidence that virulence was related to previous spray treatment. Trees of the variety Napoleon from the same nursery, and propagated from the same clonal source on the same rootstock, showed different degrees of resistance when inoculated in the orchard.

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THE ASSESSMENT OF SPORE PRODUCTION BY *GLOEOSPORIUM ALBUM* AND ITS RELATION TO FRUIT INFECTION

By R. T. BURCHILL and K. L. EDNEY*

Gloeosporium album Osterw. and *Gloeosporium perennans* Zeller and Childs exist in apple orchards mainly as saprophytes of small dead stubs and mummified fruitlets (4), where, given suitable conditions, they produce whitish pustules containing conidiospores. These spores are dispersed by rain to the fruits, causing latent infections which develop as rots during storage. Variations of spore populations within the orchard at different times during the year influence the epidemiology of the disease and the selection and timing of fungicidal sprays.

Using a trap designed to catch spores washed down branches in the ' run-off ' stream, Corke (1) observed the fluctuations throughout the year in spore density and recorded the periods of maximum and minimum discharge of conidia from *G. perennans* cankers produced by inoculation.

In April 1959, experiments were begun to develop a field technique for assessing spore production in an orchard of Cox's Orange Pippin trees known to be infected with *G. album*.

The results of these experiments and their use in relating periods of spore discharge to climatic conditions and to the infection of developing fruit are described below.

Materials and methods

Spore collection

Spores were collected with traps basically similar to those designed by Corke (2). A Y-shaped piece of polythene, 1 in. wide, was substituted for the aluminium gutter ; the forks of the ' Y ' were tied around the branch from which the collection was being made, with the base in the top of the collecting tube. Five branches from each of twelve 25-year-old trees on M.IX rootstocks (Plot 1) were studied. These trees and others used in the fruit bagging experiment described below, although infected mainly with *G. album*, also carried some *G. perennans* infections as noted in the fruit infection records (Tables II and III) and in spore-trapping results (not recorded here). The selected branches bore a number of infected stubs and were either growing vertically or at an angle of not more than 45° to the vertical, thus ensuring that rain falling on them flowed into the collecting tube. Protuberances likely to divert this flow were removed, and a length of string was fixed by an adhesive to the undersurface of the branch to assist in channelling the water into the tube. The positions of the traps on individual trees remained unaltered during the experiment. Immediately the tubes became over half full the contents were collected and centrifuged at 3,000 r.p.m. for 15 minutes ; the spores were re-suspended in 1 ml of distilled water and their number estimated by the mean of 6 haemocytometer counts. This estimate, expressed as ' number of spores per ml ', was used to assess the spore discharge at various periods in the experiment. Trapping of spores began on 16th April 1959.

Measurements of fruit infection

The relation between the spore counts and the amount of fruit infection was studied by observing the development of rotting on samples of fruits picked at intervals from 9th June to 15th September 1959.

At the fruitlet stage a sample of 25 fruits was picked and placed in storage and in addition a number of apples on the trees were enclosed in polythene bags. Immediately after prolonged rainfall, bags were removed from a sample of 25 fruits, which remained exposed until after a period of rain in which spore counts showed that there had been a discharge of spores. This fruit was then picked, together with a control sample of 25 unenclosed fruits, and at the same time bags were removed from a further sample of 25 apples.

The development of infection by *G. album* was also studied on fruit from trees of 9-year-old Cox's on M.VII rootstocks (Plot 2). Two samples of 25 fruits which had been continuously exposed were picked on the same dates as those picked from Plot 1, and one of these samples was swabbed with a conidial suspension of *G. album* (50,000 spores/ml). The samples were then stored as described below.

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Storage of fruit

The fruit was kept at 12° C in closed glass containers adequately ventilated with moist air to prevent wilting and increase in the carbon dioxide concentration. Samples were inspected periodically and any lesions that had developed were recorded and the causal organism identified. The final count of rots caused by *Gloeosporium* spp. is given in Tables II and III. Two additional samples were picked from Plot 1, on 15th September ; one of these had been enclosed in polythene bags throughout the season and the other exposed continuously. These samples were loaded with spores of *G. album* and kept at 12° C as described above, and the numbers of rots were recorded (Table II).

Results

Seasonal fluctuation in spore discharge

Table I shows the monthly and three-monthly totals of the mean spore concentrations trapped from all trees during the 12-month period beginning April 1959. Results for individual trees followed a similar pattern although some trees yielded consistently higher concentrations of spores than others.

Spores of *G. album* were dispersed throughout the year. During the dry summer of 1959, concentrations remained relatively low but increased in the autumn, reaching a maximum of 225,500 spores per ml in November. After December the concentration fell to approximately the level obtained in the summer. There appeared to be a positive association between the total *monthly* rainfall and the concentration of spores trapped, particularly during the months October to December, but it was impossible to discern any relationship between *daily* rainfall and spore concentrations. For example, 0·5 in. of rain on 20th May yielded only 500 spores per ml, whereas on several other occasions a much lower rainfall resulted in the trapping of considerably higher spore concentrations.

TABLE I

MEAN CONCENTRATIONS OF SPORES TRAPPED EACH MONTH FROM APRIL 1959 TO MARCH 1960

Month	Rainfall (in.)	Mean concentrations of spores trapped		
		Total for month	Total for 3 months	Per in. rainfall
April	1·62	13,500		8,333
May	1·20	3,200	33,900	2,666
June	0·93	17,200		18,494
July	1·60	25,000		15,625
August	0·84	8,600	35,200	10,240
September	0·10	1,600		16,000
October	2·82	60,600		21,489
November	3·56	225,500	408,100	63,342
December	4·14	122,000		29,470
January	1·95	18,500		9,487
February	1·97	8,000	30,500	4,060
March	1·23	4,000		3,252

Fruit infection

Fruit exposed continuously.—During the summer of 1959, no infection was apparent on any samples picked before 14th August. On samples picked on that date, two rots caused by *G. album* and two by *G. perennans* were recorded. Rotting by both species also developed on the final sample, picked on 15th September. The incidence of rots in the additional sample picked at the time of normal harvest and loaded with spores of *G. album* was no higher than that in the untreated control samples picked at the same time.

Fruit exposed for a limited period.—Rots developed in all samples and clearly the susceptibility of the fruit was enhanced by enclosure in polythene. No relationship between the concentration of spores released and the incidence of rotting was apparent. On two dates, viz. 15th July and 14th August, although spores of *G. album* were dispersed immediately prior to picking, no rotting by this species developed in store. A sample which had been bagged throughout the experiment showed a high incidence of rots in store after being loaded with spores of *G. album*, a result which further demonstrates the increased susceptibility of fruit enclosed in polythene. No rots developed on fruit bagged throughout and not loaded with spores.

TABLE II

(*a*) NUMBER OF APPLES FROM PLOT 1 (COX'S ON M.IX) WITH ROTS CAUSED BY *GLOEOSPORIUM* SPP. IN STORE AT 12° C

Date of picking (1959)	9th June	1st July	15th July	30th July	14th August	15th September
Exposed for a limited period	—	1A + 3P	2P	4A	9P	2A (14 in sample)
Exposed continuously	—	—	—	—	2A + 2P	9A + 1P

A = *G. album*. P = *G. perennans*. Sample size 25 apples.

(*b*) SAMPLES FROM PLOT 1 PICKED ON 15TH SEPTEMBER LOADED WITH *G. ALBUM* AND STORED AT 12° C

Bagged throughout 19A + 3P
Exposed throughout 7A + 1P

TABLE III

NUMBER OF APPLES FROM PLOT 2 (COX'S ON M.VII) WITH ROTS CAUSED BY *GLOEOSPORIUM* SPP. AFTER LOADING WITH SPORES OF *G. ALBUM* AND STORAGE AT 12° C

Date of picking (1959)	9th June	1st July	15th July	30th July	14th August	15th September
Control ..	—	—	—	—	—	4A + 1P
Loaded with spores ..	—	—	—	2A	3A + 1P	20A + 1P

A = *G. album*. P = *G. perennans*. Sample size 25 apples.

No rots developed on untreated control fruit picked before 15th September. A small number of the apples loaded with spores were infected in the two preceding picks (Table III), but not until the final pick was there a marked response to loading when 20 of the sample of 25 developed lesions. This result was contrary to past experience (3), where there has been no marked increase in rotting of Cox's fruit following this treatment.

Discussion

Spores were produced by *G. album* throughout the year, although the numbers fluctuated.

During the period April 1959-March 1960, there was some evidence that spore concentrations were related to the monthly rainfall ; this was not surprising since wet conditions should favour both the production and liberation of spores from fungal fructifications. Whether such a relationship occurs every year is not yet known, but it is clear that some factor other than rainfall is involved in spore production ; thus when allowance is made for the amount of rainfall by computing spore concentrations per ml per in. of rainfall, concentrations are still considerably higher from October to December than at other times in the year (Table I). Monthly collections of stubs induced to sporulate by incubation at 15° C under moist conditions confirmed that spore production increased in the autumn. Corke (1) noted a similar increase with *G. perennans*, although maximum sporulation for this species occurred in September.

It has not been possible to relate the development of rots on fruit in storage with particular periods of spore discharge during the growing season, possibly because of the restricted movement of spores in the dry summer and also because the methods used to delimit infection periods affected the susceptibility of the fruit. Enclosing fruits in polythene, for example, increased their susceptibility to rots, thus vitiating any direct comparison with the exposed controls. Fruit picked at intervals during the season also failed to give an indication of spore dispersal, as the number of rots developing in store

appeared to be related more to the maturity of the fruit at picking than to the number of spores to which they had been exposed.

The potential value of spore traps in relating periods of spore discharge to the rainfall and to the infection of the fruit has been noted. Their use in the field as a means of studying the effect of eradicant fungicides on sporulation is under investigation. If successful, this technique could provide an early assessment of such treatments and also indicate whether additional applications are necessary.

Summary

Measurements of spore populations of *G. album* in an orchard of Cox's Orange Pippin trees from April 1959 to March 1960 have shown that the spores are dispersed throughout the year, with a maximum discharge in the autumn. Samples of fruit continuously exposed or protected by polythene bags for various periods were collected at intervals during the growing season, and stored at 12° C to determine if there is any relationship between spore counts and fruit infection. These, and other samples infected artificially, demonstrated that the incidence of rotting was determined by the maturity of the apples rather than by the quantity of inoculum to which they were exposed.

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TOLERANCE TO VERTICILLIUM WILT DISEASES IN THE STRAWBERRY

By P. W. TALBOYS, MARGERY BENNETT, and J. F. WILSON

Strawberry wilt is fairly common in commercial plantings in E. Anglia, Kent and Hampshire, and has been recorded in Worcestershire, Hertfordshire, Sussex, Ayrshire, and Argyll (5).

Both *Verticillium albo-atrum* and *V. dahliae* are known to cause the disease in Britain (4) though *V. dahliae* is generally the more prevalent. Most North American reports refer to *V. albo-atrum* as the causal organism, but this probably reflects a concept of the species different from that generally accepted in Britain (3) and there seems little doubt that the organism primarily concerned corresponds with that commonly known in this country as *V. dahliae*.

The first detailed account of strawberry wilt (10) referred to the existence of varietal differences in resistance to the disease. Subsequent reports of varieties showing tolerance of or resistance to wilt have come from workers in California (1, 11, 14), New Jersey (13), British Columbia (12), and New Zealand (2).

Keyworth and Bennett (4) have reported experiments on varietal susceptibility to *V. albo-atrum* on two sites in Kent. In the first trial, carried out in 1946 on a heavy clay loam soil, seventeen varieties were represented. They were planted on a site which had previously been used for trials of wilt resistance in hops, and no new inoculum was added to the soil. The resulting incidence of diseased plants ranged from 4% in King George and 15% in Royal Sovereign to 54% in Tardive de Leopold and Early Cambridge.

In 1947 nineteen varieties (including twelve which were represented in the previous experiment) were tested on a medium sandy loam, but on this occasion inoculum consisting of 10-12 g of chopped hop bine infected with *V. albo-atrum* was placed under each plant. All the varieties were severely affected and none showed less than 85% wilted plants. From this it was inferred that though there may be varietal differences in wilt resistance, such differences may not be apparent under conditions favouring the disease, so that the use of resistant varieties was considered unlikely to provide a satisfactory means of control.

In 1955 an outbreak of Verticillium wilt occurred in a strawberry variety trial at the National Fruit Trials, Brogdale (6). *V. dahliae* was the causal pathogen, and varietal differences in the incidence of the disease were obvious : relatively few plants (10-15%) were affected in the varieties Merton Princess, Redgauntlet, Cambridge Premier, Royal Sovereign, and Talisman ; the disease was most severe in Cambridge Vigour (46·5%) and Huxley (37·9%), while in Cambridge Regent, Mme. Lefebvre, Perle de Prague, Cambridge Rearguard, and Early Cambridge the wilt incidence ranged between 20% and 30%. This suggested that even if resistant varieties would not satisfactorily control wilt caused by *V. albo-atrum* they might with advantage be used against the more prevalent *V. dahliae*.

Further experiments on wilt resistance of a number of strawberry varieties were initiated in 1957.

1957 Experiment

Methods

This trial was designed to investigate differences between varieties in respect of the number of plants developing the disease, and of the severity of the symptoms. It consisted of four blocks of randomized 5-plant plots of each of the varieties Royal Sovereign, Cambridge Premier, Talisman, Cambridge Vigour, Early Cambridge, and Huxley.

The plants were grown in John Innes No. 1 compost in 5-in. pots plunged in gravel in concrete tanks, the construction of which has been described by Talboys and Wilson (9). In late April, after the plants had become well established, they were inoculated with a pure culture of *V. dahliae* growing on sterilized chopped hop bine. Each was knocked out of its pot and about 10 g of the inoculum was placed at the bottom of the pot and covered with a layer of the compost ; the plant was then replaced.

At fortnightly intervals throughout the summer each plant received 40 ml of a 3% solution of sodium nitrate applied to the soil.

Results

At no time in the course of the trial did any variety develop the characteristic symptoms of wilt, viz. reddening and necrosis of the outer leaves accompanied by yellowing and dwarfing of the young leaves at the centre of the crown. Nevertheless, in the varieties Cambridge Vigour, Early Cambridge and Huxley the plants appeared to be slightly dwarfed, though normal in colour. No statistical comparison with non-inoculated plants was possible, but a number of such plants growing under comparable conditions near by were obviously larger than the inoculated ones.

In November eight plants of each variety (two from each plot) were removed, and transverse sections of the main crowns incubated in moist chambers at 23° C. The presence of *Verticillium* was established in 7 plants of Huxley, 5 of Cambridge Vigour, 3 of Early Cambridge and 2 of Royal Sovereign. It was not detected in Talisman and Cambridge Premier, but this test is relatively insensitive and the possibility that the pathogen may have been present in very small amounts cannot be excluded.

1958 Experiment

Methods

The previous experiment suggested that the effect of *Verticillium* infection might be limited to slight dwarfing of the plant ; the 1958 experiment therefore included non-inoculated control plots to enable such an effect to be detected. A third treatment, inoculation with an isolate of *V. albo-atrum* from an outbreak of fluctuating wilt in hops was also included to compare the pathogenicity of the two wilt-inducing species ; no isolate from strawberry was available.

The three treatments were randomized within the four blocks, and 5-plant plots of each variety were randomized within each treatment. The varieties were Royal Sovereign, Cambridge Premier, Talisman, Cambridge Vigour, Huxley, and Cambridge Rearguard. In mid-June inoculum was buried just beneath the surface of the soil, so that the root system would be subjected to a downwash of conidia for a considerable period (7). As before, sodium nitrate solution (3%) was applied at fortnightly intervals from the end of April until mid-August at the rate of 40 ml per plant.

Results

Wilt symptoms were scored as follows:

'3' : severe wilt ; plant dead or nearly so.
'2' : outer leaves dead, yellowing and stunting of young leaves.
'1' : doubtful wilt ; some old leaves dead but the rest of the plant normal, or a general stunting of the plant without other symptoms.
'0' : apparently healthy.

The scores were used to determine a mean disease rating for each variety.

As in the previous experiment, inoculation with *V. dahliae* failed to induce a typical wilt in any variety, though some very mild symptoms which developed in a few plants were attributed to the pathogen ; the non-inoculated controls showed no symptoms.

In contrast to this, inoculation with *V. albo-atrum* caused disease in all varieties. Symptoms developed first in Cambridge Vigour, about five weeks after inoculation, and this variety was the most severely affected throughout the season. Talisman was the least affected, and the other varieties formed a graded series between the two extremes (Fig. 1).

In November, records were made of the height (h) and spread (s) of each plant, and from these data the mean volume per plant for each variety in each treatment was calculated, assuming that a strawberry plant is essentially dome-shaped and that its volume approximates to $\frac{\pi h(3s^2 + 4h^2)}{24}$ (G. H. Freeman, personal communication). The results are shown in Fig. 2.

The great reduction in the volumes of plants infected with *V. albo-atrum* merely expressed quantitatively what was already obvious to the eye. In Cambridge Vigour, infection with *V. dahliae* also caused some reduction in plant size, even though symptoms were otherwise very slight. In the other varieties the presence of *V. dahliae* caused no general reduction in plant size, and indeed in Rearguard the inoculated plants tended to be slightly larger than the non-inoculated, though the difference was not significant.

It seemed probable that the environmental conditions of pot-culture were inhibiting symptom development after inoculation with *V. dahliae* ; the whole trial was therefore transferred in February 1959 from the concrete plunging beds to an experimental field plot.

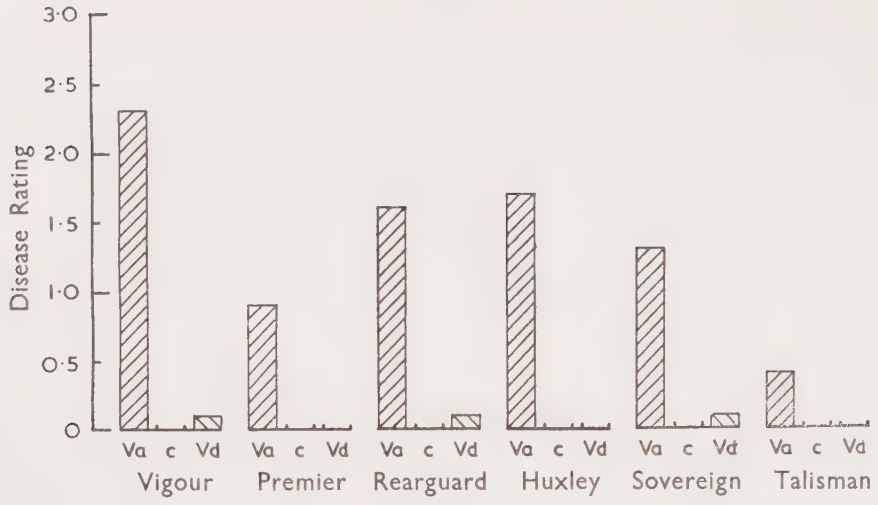

FIG. 1

Disease ratings of the trial varieties growing in the plunging-beds in September 1958
Va: inoculated with *V. albo-atrum*; Vd: inoculated with *V. dahliae*; C: non-inoculated controls

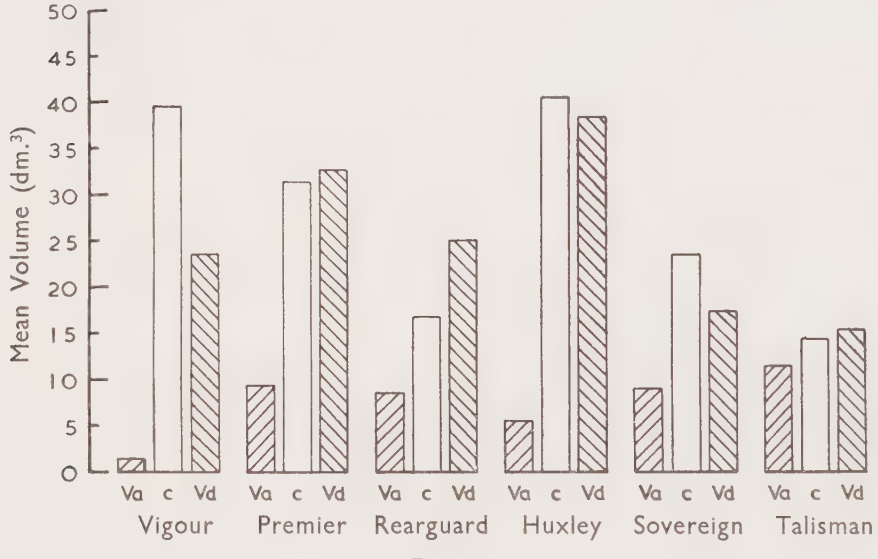

FIG. 2

Mean volume per plant of the trial varieties in November 1958

1959 Experiment

Methods

The plants from the previous experiment were knocked out of their pots and planted in the field without further inoculation. The layout corresponded with that in the plunging beds, but the spacing of the plants was greater to allow cultivation and to reduce cross-contamination.

In May the plot received meat-and-bone meal at the rate of 15 cwt per acre and sulphate of potash at 1¼ cwt per acre.

Results

By July wilt symptoms had developed in plants inoculated with *V. dahliae* as well as in those that had received *V. albo-atrum* (Fig. 3). Cambridge Vigour was the most severely affected by both pathogens, and Talisman the least.

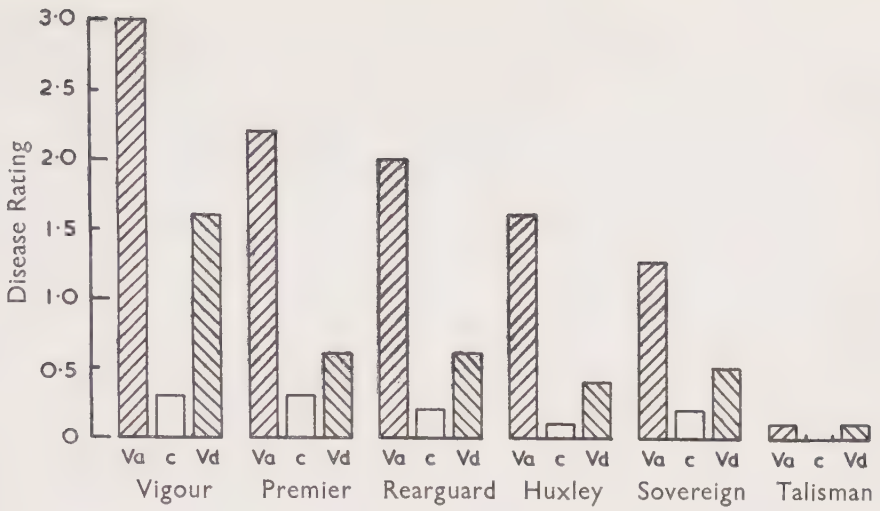

FIG. 3
Disease ratings of the trial varieties under field conditions in July 1959

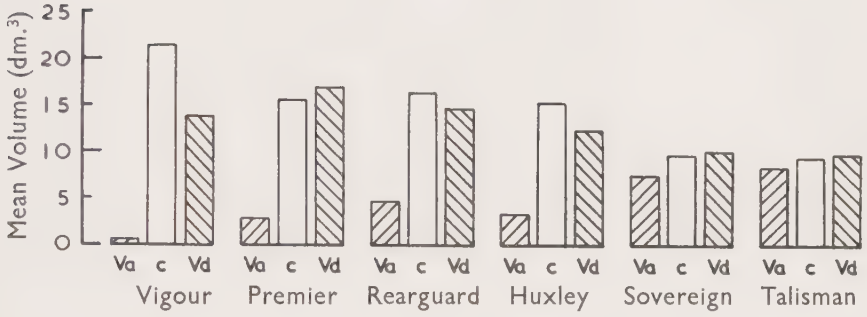

FIG. 4
Mean volume per plant of the trial varieties in July 1959

In most varieties infection with *V. albo-atrum* led to a substantial reduction in plant size (Fig. 4), though Royal Sovereign was only slightly reduced and Talisman virtually unaffected.

Cambridge Vigour was the only variety significantly reduced in size by *V. dahliae*, but this reduction in mean volume, unlike that in 1958, was mainly accounted for by the plants which showed severe symptoms rather than by the stunting of otherwise symptomless plants.

Appreciable disease ratings were recorded in the non-inoculated control plots and affected plants yielded *V. dahliae* in culture. Approximately one-fifth of the plants in the trial were removed after the final records had been made and excisions from the vascular systems of the main crowns were plated out on prune-lactose-yeast agar (8) containing 0·5% potassium thiocyanate ; no samples were taken from Cambridge Vigour inoculated with *V. albo-atrum* because all the plants were dead and rotting.

Most plants which had shown symptoms yielded the organism with which they had been inoculated ; failure to isolate the pathogen in a few cases probably resulted from selection of non-infected parts of the crown or from overgrowth of the fungus by contaminant organisms.

Plants which had developed symptoms in the non-inoculated plots were again found to contain *V. dahliae*, and this species was also isolated from two plants in the *V. albo-atrum* series. It is probable that this widespread infection resulted from the presence of the fungus in the soil before the trial was laid down rather than from spread from the inoculated plants.

In all varieties some symptomless plants yielded *V. dahliae*, and *V. albo-atrum* was similarly obtained from apparently healthy plants of Talisman and Royal Sovereign.

The relatively small size of even the apparently healthy plants is attributable to the drought conditions which prevailed during the summer of 1959.

Discussion

These experiments have confirmed that under some environmental conditions the strawberry plant is able to tolerate the presence of *Verticillium dahliae* within the vascular system without developing symptoms, though the extent of such tolerance varies with different varieties ; the conditions in the experimental plunging beds were evidently appropriate as completely symptomless plants of several varieties, including Cambridge Vigour, were found to be infected.

Cambridge Vigour was subsequently shown to be the most acutely sensitive of the varieties to *V. dahliae* under field conditions ; Royal Sovereign, Cambridge Rearguard, Cambridge Premier, and Huxley were all moderately tolerant, while Talisman showed relatively high tolerance. The behaviour of Huxley was more satisfactory than would have been expected in view of the high wilt incidence in the plots of this variety in the National Fruit Trials.

It has not been possible to define the factors which lead to symptom expression or suppression in the presence of *V. dahliae*. Field observations suggest that the disease tends to be more severe when the early summer is dry and warm than when it is wet and cool ; wilt also tends to be more severe on light, well-drained soils, and possibly the very moist conditions prevailing in the plunging beds were not conducive to symptom expression.

V. albo-atrum was much more pathogenic than *V. dahliae*, and environmental differences had much less effect on the severity of the disease. Only Talisman showed a high degree of tolerance. Cambridge Vigour was extremely sensitive, and none of the inoculated plants of this variety survived beyond the early summer of their second year. In the other varieties many plants showed severe symptoms, but relatively few were completely killed.

Though Talisman showed marked tolerance towards both *Verticillium* species it does not necessarily follow that growing such a variety will alone provide an immediate and complete answer to the wilt problem on badly affected land, nor can it be assumed that a high degree of tolerance will permit a variety to be grown repeatedly on the same site and still remain free from the disease.

The use of tolerant varieties will enable the pathogen to persist in the soil indefinitely, and possibly to accumulate there ; the potentiality for disease development under appropriate environmental conditions will therefore remain, and may even increase. To maintain a relatively disease-free condition it is desirable periodically to reduce the infectivity of the soil to the lowest possible level ; this implies either the use of crop rotations excluding such *Verticillium* hosts as potatoes and raspberries and preferably including grasses or cereals which are highly resistant or immune, or of partial sterilization of the soil with a volatile fungicide. Soil fumigation with chloropicrin has been used to control strawberry wilt with considerable success in California (15), but little information on its effectiveness under British conditions is available at present.

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Summary

Verticillium albo-atrum was found to be more pathogenic to strawberry than the more prevalent *V. dahliae*.

Talisman showed a high degree of field tolerance to both species ; Cambridge Premier, Cambridge Rearguard, Huxley, and Royal Sovereign were moderately tolerant to *V. dahliae*, but only slightly tolerant towards *V. albo-atrum* ; both species induced severe disease in Cambridge Vigour.

Under the very moist conditions of pot-culture in plunging beds all varieties were tolerant to *V. dahliae*, but only Talisman showed marked tolerance to *V. albo-atrum*.

It is suggested that the use of tolerant varieties in the control of these diseases should be combined with periodic measures to reduce soil infectivity, e.g. by rotation or soil fumigation.

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MACHINE PICKING IN RELATION TO PROGRESSIVE VERTICILLIUM WILT OF THE HOP

I. A STUDY OF THE INFECTIVITY OF MACHINE-PICKED HOP WASTE

By G. W. F. SEWELL and J. F. WILSON

During the last decade the number of hop-picking machines in use has increased rapidly. Half the hop acreage in south eastern England was picked by about 260 machines in 1959 (5), and over 82% of the West Midlands acreage was machine-picked in 1958 (2).

As no satisfactory mobile picking machine is at present available to the industry, all aerial parts of the plants are cut down and transported to the machine, and the residues (consisting of bine, lateral branches, leaves and parts of shattered cones) are deposited in its immediate vicinity. Since an acre of hops may yield from three to five tons of green waste matter, the accumulated mass of waste is very great.*

In areas where hops that are affected by the virulent (or progressive) strain of *Verticillium albo-atrum* Reinke and Berth. are picked by machine, there is growing concern at the risks of spreading the disease during the movement of bines to the machine (often along public roads), and later, in disposing of the hop waste.

The problems associated with the machine-picking of hops from Verticillium-infested land are being studied jointly at the Department of Hop Research of Wye College and at this Station. The investigations described below form part of the study and deal, firstly, with the varying degrees of apparent and latent infection which can occur in wilt-sensitive and wilt-tolerant varieties, and secondly, with the infectivity of different fractions of machine-picked hop waste.

Symptom expression in relation to the distribution of Verticillium in hop plants

Wilt-sensitive varieties

In a completely wilted hop plant Verticillium may be present in all aerial tissues except the bracts and bracteoles of the cones (6) ; in partly wilted bines the distribution of the fungus usually coincides closely with the visible foliar symptoms. Sensitive varieties may also be infected with progressive wilt without showing symptoms. Such a situation may arise in two ways :—

(i) When infection occurs late in the season, the fungus may by picking time have colonized only those parts of the bines which have been stripped of leaves, or where old leaves are senescing, and wilt symptoms are consequently masked.

(ii) It has been shown experimentally that infection of sensitive varieties by very low levels of inoculum may give rise to limited sectorial colonization of bine vascular tissue, and that plants thus infected may sometimes remain symptomless throughout the season.

In both instances Verticillium may be present in the bines above the height at which they are cut for machine-picking, and infected material will pass through the machine. Furthermore, after the bine is cut, the fungus probably colonizes the tissues more extensively and quickly. The rapid colonization of dying and moribund host tissues by Verticillium, ensuring the production of great quantities of infective material, has previously been noted (6, 7, 8).

The following example of progressive wilt infection in a commercial garden indicates the comparatively high level of latent infection which may occur in a sensitive variety. An area of land, which had previously been under cereals for seven years, was planted with the wilt-sensitive variety Northern Brewer : this land was soon contaminated with infected plant debris (by cultivating implements) from an adjoining garden planted with a tolerant variety. In the second year after planting, detailed records of foliar (wilt) symptoms were made in three areas of the new garden. In addition, as every bine was cut for machine-picking, it was examined for signs of vascular infection. The records are summarized in Table. I.

* When hops are picked by hand the bines are pulled from the top wires but remain attached to their roots. After picking, the bines are loosely coiled, and when dry are collected and burnt within the hop garden.

TABLE I

PERCENTAGES OF INFECTED HILLS WITH AND WITHOUT WILT SYMPTOMS IN A COMMERCIAL GARDEN OF THE SENSITIVE VARIETY NORTHERN BREWER

Situation of garden	Total no. of hills	Infected bines %	
		Wilted	Symptomless
Adjacent to wilt-infected plantation	585	4·1	8·4
Distant from wilt-infected plantation	540	0·2	2·4
Distant from wilt-infected plantation	702	0·1	0·9

It must be emphasized, however, that symptomless infection of sensitive varieties, by progressive wilt, differs from that in tolerant varieties in being only a temporary phenomenon—such plants usually wilt and die early in the subsequent season.

Wilt-tolerant varieties

In the south-eastern hop growing area, 1,500 acres of the 5,000 affected by progressive wilt are planted with wilt-tolerant varieties (5), which have a high level of resistance owing to the restriction of the fungus in the vascular tissues (9). No variety is known that is immune to infection, and hence all are potentially symptomless carriers of the virulent strain of *V. albo-atrum*. Occasionally they may show slight wilt symptoms in one or a few bines, but all the bines of a hill are seldom wilted and even more rarely are hills killed. When well established, tolerant varieties grown on Verticillium-infested land seldom show appreciable signs of infection and consequently growers sometimes forget that the land is still infested. For this reason particular attention is given in this paper to the dangers of spread of progressive wilt associated with machine-picking of tolerant varieties.

Symptomless infection of tolerant varieties was studied during 1960 in well-established gardens on ten seperate farms (A-J). The selection of these gardens was based on the results of a survey carried out in 1958 with the co-operation of the Association of Growers of the New Varieties of Hops : this showed that unusually high levels of wilt (of a fluctuating type) had occurred in tolerant varieties on ten farms. Five of these (F-J) were investigated, together with a further five ' control ' farms (A-E) with similar soil types, cultivation and cropping histories. These control farms showed the normal, low or negligible levels of wilt. The five farms (F-J), therefore represent a minority of farms on which wilt incidence in tolerant varieties is unusually high.

On each of the 10 farms, representative sample plots consisting of about 500 hills were recorded for visible wilt symptoms up to picking-time, and immediately after picking every bine on each hill was examined for signs of vascular infection. The results (Table II) show clearly that the hills with wilt symptoms were only a small proportion of those infected. Although there was a marked tendency for the number of infected symptomless hills to increase with the number visibly wilted, the actual ratio of these two figures was very variable and the number of infected symptomless plants was up to seven times the number showing symptoms.

TABLE II

PERCENTAGES OF VISIBLY WILTED AND INFECTED SYMPTOMLESS PLANTS IN TEN COMMERCIAL GARDENS OF TOLERANT VARIETIES

Farm	Variety	Total no. of hills recorded	(i) Percentage of hills with wilt symptoms	(ii) Percentage of hills infected but symptomless	Ratio (ii)/(i)
A	OR55	495	0·0	2·2	∞
B	OR55	486	0·4	1·4	3·5
C	WGV1147	497	0·6	3·2	5·3
D	WGV1147	455	1·2	1·9	1·6
E	WGV1147	493	1·2	8·7	7·3
F	OR55	495	3·6	15·2	4·2
G	OR55	508	14·0	24·0	1·7
H	WGV1147	576	14·8	14·2	1·0
I	WGV1147	674	19·5	21·1	1·1
J	WGV1147	472	22·0	25·4	1·2

Thus, assuming that inspection of gardens and removal of all visibly wilted hills were to continue up to the time of picking, a considerable quantity of infected material would still pass through the machine. In practice, even where wilt inspections are carried out regularly, they commonly cease with the approach of picking and some plants with definite wilt symptoms are harvested (see Table III).

An experiment to test the infectivity of fractions of hop residues

Materials and methods

Residues of the tolerant Whitbread's Golding Variety 1147 were used throughout. The term 'bine' refers to the main vertical stems, and 'trash' refers to all other aerial residues consisting of thin lateral branches, leaves, and parts of the shattered cones.

The following three classes of residues were collected :

(i) *From fully wilted hills.*—All aerial parts of wilted plants were collected during the late summer 1959.

(ii) *From infected plants not showing foliar symptoms.*—This material was collected during the picking period as the bines were cut (about 30 in. above soil level), prior to their being removed from the top wires. The cut surfaces were examined for the vascular discoloration which characterizes Verticillium infection ; where this occurred in one or more bines of a plant, all the aerial parts were collected. This material would normally have passed through the picking machine.

(iii) *Hop picking machine waste.*—A plot of 1,525 hills in a commercial garden was recorded for external wilt symptoms on the day before picking (Table III). Immediately after the bines had been cut, and prior to their removal from the garden, all bines were examined for vascular discoloration. A random sample of the waste from these same bines was later collected from the picking machine ; this sample consisted of chopped bine mixed with trash.

TABLE III

INCIDENCE OF WILT AND SYMPTOMLESS INFECTION IMMEDIATELY PRIOR TO MACHINE PICKING

Total number of hills examined	1,525
Percentage showing wilt symptoms* ..	4·8
Percentage symptomless infected	12·7
Total percentage infected	17·5

* The plants in this category were harvested.

After collection, the residues were air dried to reduce fermentation processes to a minimum, and then separated into bine and trash fractions. The resultant six classes of residues were stored under dry conditions until used as inoculum.

The infectivity of this material was tested on land on which wilt-sensitive hop varieties had been grown for ten years prior to the winter of 1959/60 : during this period they had remained free from Verticillium infection.

In March 1960, the residues were weighed into 4 oz aliquots which were placed beneath setts of Fuggle N on planting. Twenty-one Fuggle plants were used to test bine or trash from visibly wilted hills or from infected symptomless hills ; 42 test plants were used for each of the two classes of machine waste, and 21 uninoculated plants were included as controls. Within treatments plants were divided into 7-plant plots, distributed at random in three blocks. The land available for the experiment was limited and gaps of only 5 or 7 ft separated the plots.

Results

The test plants were inspected regularly throughout the period of the experiment. As soon as definite wilt symptoms occurred affected plants were cut down and carefully removed from the experimental plot. The first definite wilt symptoms were recorded on 15th June, and symptoms continued to develop until 7th September, when all remaining bines were cut and examined for vascular discoloration.

The results are presented graphically in Fig. 1. All classes of residues induced visible wilt symptoms in a high proportion of test plants, and all plants surviving at the end of the experiment were found to be infected except for 13% of those inoculated with machine waste trash. In one of the uninoculated plots two plants wilted late in the experiment and a third was found to be infected at the final sampling : these infections were probably due to the narrowness of gaps between plots.

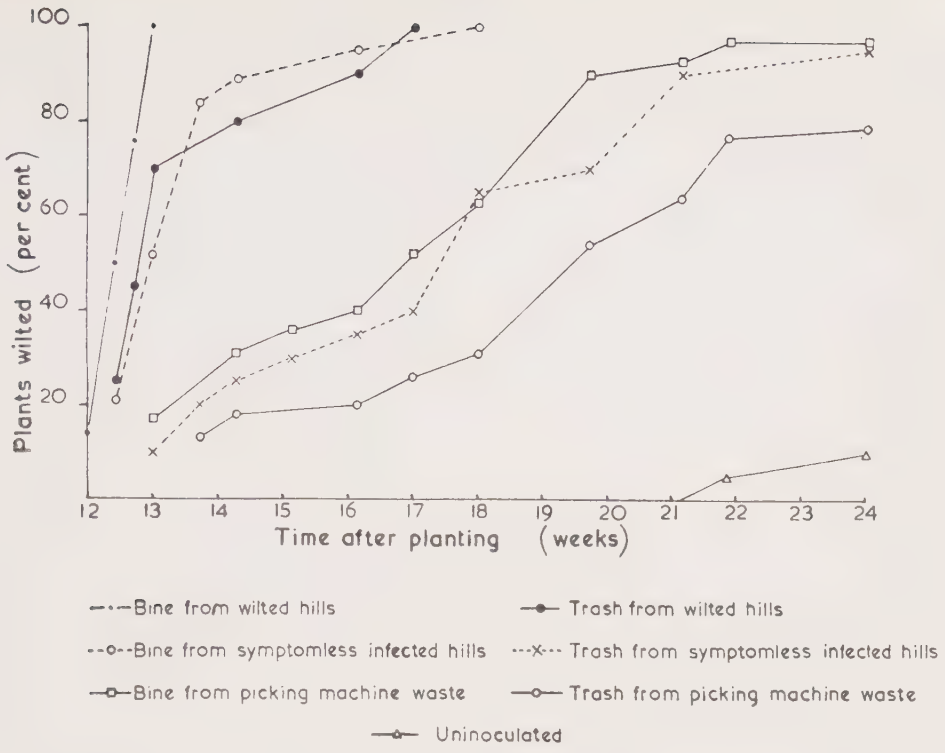

FIG. 1

Rates of wilting of Fuggle N induced by bine and 'trash' of W.G.V. 1147 from differentially infected plants and from hop picking machine waste

Controlled inoculation experiments have shown that the rate of wilting of hops is often closely related to the inoculum concentration, and the respective rates of wilting in the present experiment, therefore, probably indicate the inoculum potentials (4) of the various types of residues. Although bine always caused more rapid wilting than the corresponding trash fraction, there was a tendency for the three classes to overlap ; for example, the infectivities of bine from infected symptomless hills and trash from wilted hills were closely comparable, as also were the infectivities of bine and trash respectively from machine waste and infected symptomless hills. Thus, the six types of residues (from wilted plants, infected symptomless plants, and machine waste) formed a graded series of decreasing inoculum potential.

Discussion

Infection by the virulent strain of *V. albo-atrum* can occur without symptoms in both wilt-sensitive and wilt-tolerant varieties of hop. The use of picking machines involves the harvesting of infected material and consequent spread of infection. The highly infective nature of hop waste, from a garden with 4·8% apparent and 12·7% symptomless infection, was demonstrated experimentally. Growers have already been warned that progressive wilt may be spread during the transport of bines (often along public roads) to picking machines, and as a result of the subsequent disposal of the hop waste (1, 3).

Precise information on the survival of Verticillium in composted hop waste is not yet available. It is known, however, that lethal temperatures may be reached in certain parts of the compost heaps (10), so that efficient composting may prove a satisfactory means of rendering hop waste innocuous. In the mean time the danger of spreading inadequately composted material onto hop land is indicated by the following observation made by Keyworth (6) : ' It was clearly shown on one farm that manuring the soil with compost containing infected bines greatly increased the number of infected hills. In the summer of 1937 the grower had noticed about fifty wilted hills scattered in small patches throughout an 11-acre field. The bines from this field were collected in the autumn and put on a compost heap, and the following spring this compost was spread over most of the field, the only untreated portion being

about thirty rows at one end. In the summer of 1938, 650 wilted hills were found scattered over the whole of the treated portion of the field, while the part which did not receive any hop bines was free from wilt.'

In the present state of our knowledge burning is the only safe method of disposing of infected hop waste, difficult and wasteful as this may be. Should this be impracticable, however, every attempt should be made to reduce the infectivity of machine waste by inspecting every bine at picking time and burning in the garden all aerial parts of hills with one or more of the bines showing 'brown wood' (this task could be accomplished by the inclusion of one extra man in the field gang). The machine waste should then be carefully composted in heaps with minimum surface area and insulated against loss of heat. The resulting compost should on no account be returned to hop land, but should be spread on grassed orchards of apple, pear or cherry which are not due to be replanted within ten years of the final compost application ; wherever possible, the compost should be applied to the same land each year.

The adoption of stringent measures to prevent the scattering of plant fragments during transport from the garden to the picking machine (particularly on public roads), and the adoption of adequate guards to prevent wind-dispersal of hop debris as it is blown from the machine, are also strongly recommended. These two factors would repay consideration when the site for a new picking machine is being planned.

New disease problems are always likely to arise with changes in farming practice. The special dangers associated with machine-picking cannot be over-emphasized, but it must be borne in mind that these changes in picking practice could also help to check the spread of Verticillium wilt ; the balance will largely depend on the adoption of such control measures as have been suggested. The dropping and 'blowing' of hop fragments are more easily controlled than the movements of hand-pickers and their children, and even though hand-picked bines are dried *in situ* and burnt, the mass of infected leaf debris is shed and may be widely distributed long before the bines are collected for burning. With machine-picking all aerial parts are removed green and intact from the garden, and the main avenue of spread of Verticillium from its 'fixed' place in the soil can be effectively blocked by the destruction of the accumulated picking waste.

Summary

Infection by the virulent, or progressive, strain of *V. albo-atrum* can occur without symptoms in both wilt-sensitive and wilt-tolerant varieties of hop. The harvesting of such symptomless infected plants for machine-picking involves the transport of infected material (often along public roads) to the machine, and the accumulation of very large quantities of infected hop-waste in its vicinity. The highly infective nature of this waste was demonstrated by a field experiment.

Attention is drawn to the increased risks of spreading progressive wilt associated with the change from hand- to machine-picking, and measures to minimize these risks are recommended.

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FIG. 1

Leaves of Fuggle showing—*Left:* chlorotic banding of tertiary veins. *Right:* interveinal chlorosis

YELLOW NET—A VIRUS DISEASE OF HOP

By J. T. LEGG and P. J. ORMEROD

In 1955 two Fuggle hop plants with interveinal chlorosis of the leaves were received from Miss C. L. Jary (Hops Advisory Officer, N.A.A.S.). Similar symptoms have since been found on Bullion and Fuggle hops, but only in four plantations each with a few affected plants.

On infected plants the small (tertiary) veins of young leaves are banded by yellow tissue. This chlorosis becomes more extensive as the leaf matures, but the primary and secondary veins usually remain banded by green tissue (Fig. 1). There is no distortion of the lamina, and no obvious effect on plant vigour.

Transmission

The virus causing these symptoms has been transmitted by bottle-grafting stems from an infected hop plant to healthy Fuggle plants. Thirteen of the seventeen plants grafted in this way developed typical symptoms in the following year. The virus was also graft-transmitted from one of these infected plants to other Fuggle plants.

Mechanical inoculation with sap from young hop leaves, diluted with phosphate buffer, pH 8·3, did not induce symptoms in the test plants, *Chenopodium amaranticolor* Coste and Reyn. and *Petunia hybrida* Vilm.

Discussion

Hop mosaic virus (5) causes chlorotic vein banding but stunts and kills the infected hop plant. Even the mild strain of this virus (4) has some effect on vigour, and in addition rarely causes vein banding. With hop chlorotic virus (6), the chlorosis is white and initial vein banding is usually restricted to basal lobes, whilst the centre lobe is frequently curled downwards.

It is difficult to make direct comparison with the hop virus diseases described in Central Europe because different varieties are grown there. The two viruses, virus chlorosis (1) and chlorotic mosaic (2), cause chlorotic vein banding, but both also produce leaf necrosis, leaf distortion, and stunted plants.

The failure of *C. amaranticolor* and *P. hybrida* seedlings to develop symptoms after mechanical inoculation with sap from infected hop plants suggests that the virus is distinct from the many plant viruses that affect these hosts (3).

As the symptoms produced in hop are unlike those of any hop diseases previously described the name ' hop yellow net ' is suggested for the disease and for the causal virus.

Summary

A virus disease characterized by interveinal chlorosis of hop leaves is described ; the name hop yellow net is proposed for the virus which was transmitted by grafting but not by sap inoculation of herbaceous hosts.

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THE INFLUENCE OF A LATENT VIRUS ON THE DEVELOPMENT OF NETTLEHEAD DISEASE IN HOP

By J. T. LEGG

Nettlehead disease occurs in several varieties of hop but is most prevalent in Fuggle, the variety which has been used as an indicator for the virus until recently. The severity of the disease varies from plant to plant, but attempts to show that the variation is due to different virus strains have been inconclusive. For instance, when a clone was propagated from a mildly affected Fuggle plant, six plants developed severe symptoms and seven produced mild symptoms.

In 1951 plants of the variety Early Prolific, obtained from Prof. Lecrenier, Gembloux, Belgium, were found to be more sensitive than Fuggle to nettlehead virus. Symptoms were more severe on Early Prolific plants and developed in 6–8 weeks after graft-inoculation, compared with 5–12 months on Fuggle (2) (Fig. 1). Leaf-cupping is particularly marked on Early Prolific plants, often accompanied by a considerable reduction of the lamina (Fig. 2) ; conspicuous enations develop on the abaxial surface of the leaves but are rarely found on Fuggle.

The possibility was tested that a latent virus, similar to that reported by Frazier (1) in *Fragaria vesca*, induces the sensitivity of Early Prolific to nettlehead.

Materials and methods

Plants of Fuggle (N clone) and Bramling (E.M.R.S. clone) were each inoculated from Early Prolific by bottle-grafting. In the following year single-node green-wood cuttings from each of the two treated plants were propagated in mist. No symptoms were seen on these plants or on their progeny which are referred to as the Fuggle (X clone) and the Bramling (X clone). Young, vigorously growing plants of the Fuggle (N clone) and of the Fuggle (X clone) were infected with nettlehead virus by bottle-grafting with scions from a ' stock ' nettlehead-infected plant, while another nettlehead stock plant was used to inoculate plants of the Bramling (E.M.R.S. clone) and Bramling (X clone). Five plants of each clone were inoculated in April ; two different nettlehead sources were used because Fuggle is a carrier of hop mosaic virus to which Bramling plants are sensitive.

In a second test, five plants each of the Fuggle (N clone) and Fuggle (X clone) were bottle-grafted with stems from another nettlehead-infected plant freshly collected from the field.

Results

Six weeks after inoculation all the Fuggle (X clone) plants and four of the Bramling (X clone) plants in the first test had produced nettlehead symptoms, whereas symptoms did not develop on the Fuggle (N clone) plants and Bramling (E.M.R.S. clone) until the spring of the following year. Furthermore, all the Fuggle (X clone) plants and one of the Bramling (X clone) produced severe symptoms similar to those caused by nettlehead in Early Prolific.

In the second test, three plants of the Fuggle (N clone) and three of the Fuggle (X clone) developed mild nettlehead symptoms 6 weeks after grafting.

Discussion

In the first test a factor had evidently been transmitted to the two X clones that increased their sensitivity to nettlehead virus. The most probable graft-transmissible factor is a latent virus for which the name ' hop latent virus X ' is proposed.

In the second test both the Fuggle (N clone) plants and Fuggle (X clone) plants developed symptoms within 6 weeks. Such rapid symptom development was not encountered previously in the Fuggle (N clone) at East Malling, and it is probable that the latent virus X was present in the nettlehead source plant collected from the field. Symptoms on the six test plants were not unusually severe, however, and therefore the most reliable criterion for detecting the latent virus X is the time taken for symptoms to develop after inoculation, i.e. about 6 weeks if latent virus X is present compared with 5–12 months if it is absent.

The latent virus X is apparently present in all clones of Early Prolific at East Malling, since these all rapidly develop severe symptoms after inoculation. Little is known about its distribution

Fig. 2
Symptoms of nettlehead in Early Prolific

Fig. 1
Symptoms of nettlehead in Fuggle

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in commercial plantations as no naturally-infected plants have recently been tested for nettlehead. The latent virus was apparently present in the plant used as a source of nettlehead in the second test, but there was no indication of its presence in the plants used for the graft-transmission tests by Keyworth and Davies (2).

Summary

Plants of the hop varieties Fuggle and Bramling became more sensitive to nettlehead virus after they were grafted with scions of the variety Early Prolific. The extreme sensitivity of the latter appears to be due to a latent virus (termed hop latent virus X) which shortens the incubation period of nettlehead virus and may also increase the severity of symptoms.

References

(1) Frazier, N. W. (1953). A latent virus of *Fragaria vesca*. *Plant Dis. Rep.*, **37**, 606–8.
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ENTOMOLOGY

A COMPARISON OF PITFALL TRAPPING AND SOIL SAMPLING IN ASSESSING POPULATIONS OF TWO SPECIES OF GROUND BEETLES (COL.: CARABIDAE)

By J. B. BRIGGS

During preliminary experiments to find effective control measures for *Harpalus rufipes* (Deg.), the strawberry seed beetle, and *Feronia melanaria* (Illig.), both of which damage strawberry fruits, attempts were made to assess the efficiency of the insecticidal treatments by trapping beetles in pitfall traps. Due to robbing of the traps by magpies (*Pica pica* (L.)) between dawn and the usual time of inspection at about 0830 hr G.M.T., modifications became necessary. Further trials with modified traps suggested that they were not a satisfactory method of assessing population changes, and later work compared trapping and soil sampling on the same plot. The experiments were undertaken between 1952 and 1959 whenever facilities were available.

Biological notes

Details of the biology of both species will be published later, but the following facts are relevant to the present paper. *H. rufipes* overwinters in both adult and larval stages, the former becoming active in April and May, the latter maturing from late July onwards. *F. melanaria* overwinters principally as a larva with adults emerging in June. Since very few larvae or adults of either species have been found in strawberry beds in winter, adult population increases occurring later must be due to immigration. As *melanaria* is wingless and *rufipes* flies only rarely, and both species are nocturnal, the immigration takes place over the soil surface at night.

Methods

Traps.—Initially the trap consisted of a 1 lb jam jar sunk into the ground with the rim flush with the surface, the surrounding soil being kept firm and free from weeds and the jars cleaned frequently to prevent the escape of beetles. The traps were later modified by the addition of guards, either as a solid metal disc or a square of wire mesh, slightly larger than the diameter of the trap and held in place about one inch above it, at first by four vertical wire legs but later, to avoid disturbing the soil when emptying the trap, by a stiff horizontal wire which could be swivelled on a stake placed about one foot from the trap.

Another type of trap, consisting of a roofing tile laid on the surface of the soil with three layers of moist sacking beneath, almost completely failed to catch any beetles.

Soil samples.—Each sample area, with a strawberry plant at its centre, measured 3 ft × 18 in. This was excavated to a depth of 4 in. with a trowel, the soil being thoroughly searched as it was crumbled over a sheet. The soil was resifted and on only two occasions in 400 samples were further beetles recovered, showing that the initial inspection gave virtually 100% recovery. More detailed sampling has also shown that the beetles are present only in the top inch or so of soil during the summer months.

Layout.—The experiments were carried out in strawberry plantations of the varieties Royal Sovereign or Auchincruive Climax, varying in area from 200 to 750 square yards with plants spaced at 18 in. × 3 ft. In 1952 and 1953, the traps were sited at regular intervals, midway between the rows, the position of different types of trap being randomized. The site used in 1958 and 1959 comprised 12 small plots, each surrounded by an area of cultivated soil. In 1958, on each plot, one trap was permanently sited between plants in the row, and one sample was excavated on each sampling occasion. Procedure was similar in 1959, except that only four plots were used, each providing three trapping and sampling positions ; the choice of these was at random in both years.

Experiments with pitfall traps

Comparison of trap guards.—Traps with each type of guard were compared with unguarded traps from 22nd July to 27th August 1952, and compared *inter se* in a factorial experiment from 18th to 31st

August 1953, which also compared the presence or absence of water in the jars, the latter treatments being designated ' wet ' and ' dry ' respectively. There were 16 replicates of each treatment in 1952, and 42, equally split between ' wet ' and ' dry ', in 1953 (Table I).

TABLE I

MEAN NUMBERS OF BEETLES PER TRAP, 1952 AND 1953

Type of guard	1952		1953			
	H. rufipes	*F. melanaria*	*H. rufipes*		*F. melanaria*	
			Wet traps	Dry traps	Wet traps	Dry traps
Mesh	77·2	51·3	35·6	30·1	11·0	7·5
Disc	42·6	40·3	16·9	20·0	7·4	6·8
Unguarded	64·2	39·3				

On each occasion mesh-guarded traps caught greater numbers than the comparable set of disc-guarded traps. These differences were shown to be significant below the 0·05 level in every case with *rufipes* but only in the ' wet ' traps, in 1953, with *melanaria*.

The unguarded traps in 1952 contained intermediate numbers of *rufipes* and inferior numbers of *melanaria*, possibly due to a preference of the predatory birds for the latter species. Had the unguarded traps not been robbed, they might well have been the most successful as, in 17 out of 36 occasions, despite the interference by birds, the highest number of *rufipes* were caught in them.

The effect of water in the traps.—Since large numbers of beetles were often caught when rainfall had partially filled the jars, traps in which about one inch of water was maintained were compared with traps kept dry (except when overnight rain vitiated the treatment). These were the ' wet ' and ' dry ' traps referred to previously ; there were 42 of each, half mesh-guarded and half disc-guarded.

Results (Table I), showed that more beetles were trapped in the ' wet ' than in the ' dry ' traps, with the exception of *rufipes* in disc-guarded traps, but only in the case of *melanaria* in mesh-guarded traps were differences significant.

However, as the differences between treatments were maintained during wet spells when the applied treatment was largely vitiated, little faith was placed in this result, and it was considered to be due to chance or some effect other than that caused by the treatment.

Standard error.—Standard errors of the mean number of beetles per mesh-guarded trap per night were calculated, as percentages of the mean, for certain nights during the 1953 trial, including those when captures were largest and smallest. Using the data from all 42 mesh-guarded traps, they varied from 9-16% with *rufipes* and 15-34% with *melanaria*. Further calculations of probable standard error, had lower numbers of traps been used, suggested that these figures would have risen to 16-35%, and 27-53% respectively if as few as eleven traps had been used in the experiment.

The effect of climatic conditions on trap captures

Large variations often occurred in the numbers of each species trapped on successive nights, both in the 1952 trial and in others. The mean numbers in 1952 in the mesh-guarded traps, selected because this was subsequently adopted as the standard trap, were compared with the grass minimum temperature and rainfall during each trapping period (Fig. 1). Increases in numbers caught were often associated with higher temperatures and recent falls of rain. Partial correlation coefficients were calculated between the number of each species caught and grass minimum temperatures and daily rainfall. Independently of one another, each factor was both positively and significantly related to numbers of *rufipes* caught per night ($r = 0{\cdot}4497$, significant below the 0·01 level, and 0·4036, significant below the 0·02 level, respectively). The relationships were positive but non-significant in the case of *melanaria*.

A further trapping trial was carried out from 6th May until 26th September 1953, using 18 mesh-guarded traps. The traps were emptied daily, and *rufipes* was caught throughout the period, with markedly higher numbers in the month of August. *F. melanaria* was caught in very low numbers in May, but thereafter in rather greater numbers than *rufipes*. As in 1952, the chief feature was the marked night-to-night variation in numbers trapped. Partial correlation coefficients were calculated for each month, rather than for the whole season, since a strong positive effect at one period might mask a weak or negative effect at another. There was a positive relationship, significant at levels below 0·05, between numbers of both species trapped and temperature, in all months except July,

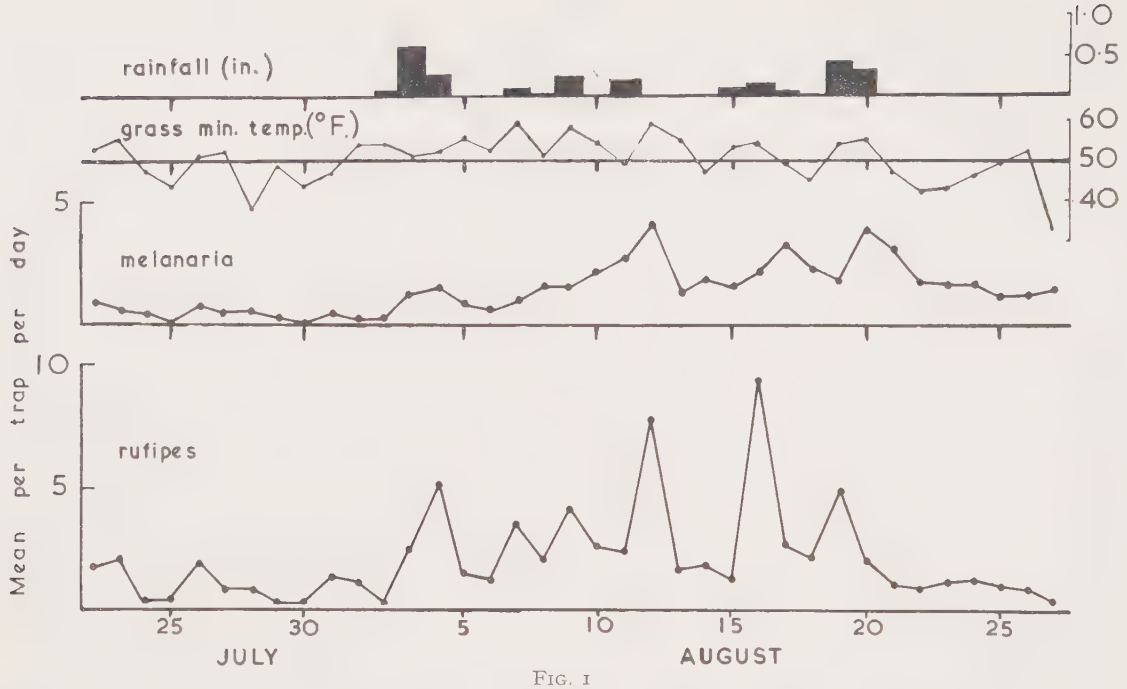

Fig. 1

Daily catch of *Harpalus rufipes* and *Feronia melanaria* compared with grass minimum temperature and rainfall, 1952

when the relationship was just negative in both cases ; the month of May was ignored for *melanaria* in view of the low catches. Relationships with rainfall were non-significant or negative except in July and August when, with *rufipes* only, there were positive correlations achieving significance below the 0·05 level.

A comparison of trapping and soil sampling

Although beetles of both species could often be more readily found beneath the plants during the fruiting period than at other times, no parallel increase occurred in numbers trapped in 1953, and in a further trial from 1954 to 1956. This suggested that numbers trapped bore little relation to the actual population present. For example, in the soil under 18 randomly selected plants, 0, 4 and 81 beetles were found on 23rd May, and 11th and 25th June respectively. Mean catches per trap per night immediately following these sampling dates were 0·2, 1·6 and 0·4.

More detailed comparisons were made in 1958 and 1959 (Fig. 2), when traps were normally emptied at two-day intervals and soil samples taken at intervals of from three to twenty-one days, the shorter intervals being used when the population was changing most rapidly. Cultural treatments included hoeing, the laying of straw and the burning off of the straw and crop residue. In both seasons, though *rufipes* was trapped from mid-May onwards, there was no real increase in numbers in soil samples until the first week in June. Populations then increased, reaching peaks on 11th July 1958 and 26th June 1959, and declining to levels similar to those found in May by 22nd July 1958 and 20th July 1959. Thereafter the population remained at a low level. The rise coincided with the laying of the straw and the ripening of the fruit, and the fall with completion of picking and burning of the straw. The dates of these events were :—

Straw laid	3rd June 1958	28th May 1959
Ripe fruit present ..	20th June-9th July 1958	10th June-2nd July 1959
Straw burnt off ..	18th-21st July 1958	17th July 1959

Results with *melanaria* were similar, although the population started to rise later, probably coinciding with, or following closely on, emergence of a new generation of beetles in nearby areas.

Trapping results showed the familiar variation in numbers recorded from one inspection to the next, illustrated in Fig. 2 by the histogram bars. There was no agreement between the erratic trap catches and the relatively smooth trend in population indicated by the soil samples. As in former

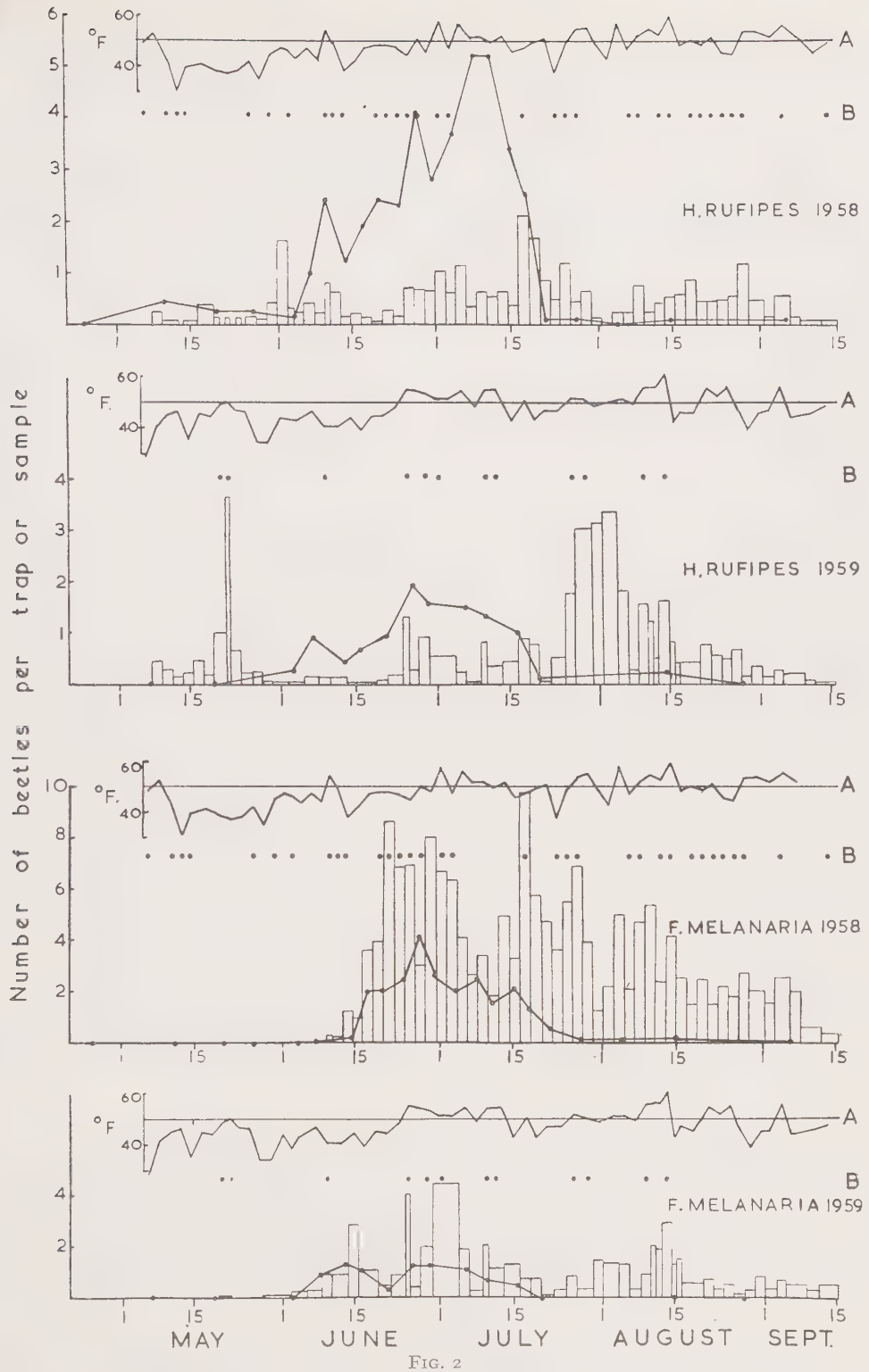

FIG. 2

Comparison of numbers of beetles in traps and soil samples, 1958 and 1959.

A. Mean grass minimum temperature between inspections.

B. Each dot denotes a period during which rain in excess of 0·1 in. fell between inspections.

Histogram bars indicate the mean number of beetles per trap per day between inspections. The *solid line* shows the mean number of beetles per sample on successive occasions

years, the true relationship of numbers trapped was with climatic factors, also shown in Fig. 2, although the visual relationship is less clear-cut because records were taken at two-day intervals.

Discussion

Since there was no apparent difference in the pattern of population changes in 1958, when trapped beetles were removed, and in 1959, when they were released at random on the plot, it was concluded that trapping had no material effect on the population.

It is evident that the size of the population plays at most a minor role in determining the numbers trapped on any occasion. The strong and generally consistent relationship between temperature and the number of beetles trapped suggests that temperature is the main determining factor. Since the function of the trap is essentially passive, it follows that higher temperatures increase the locomotor activity of the beetles, a conclusion supported by laboratory observations that will be reported fully elsewhere.

There were also significant relationships, shown to be independent of the temperature effect, between rate of trapping of *rufipes* and amounts of rain in the July-August period. In view of the lack of close relationship, for *melanaria*, and during the remaining months for *rufipes* also, and as there is a strong relationship between higher grass minimum temperature and rainfall at night, the clearer nights being in general the colder, interpretation is difficult. The general belief that ground beetles are active after rain is so strong that it has led to the use of the popular name 'rain-beetles'; but there is no evidence from this study that the two species concerned are *invariably* trapped more abundantly after rain; nor is it possible, in the instance quoted when there was a good correlation, to decide on the nature of the effect. Modification of the structure of the surface soil, and its humidity, both on the surface and in the top centimetre or so, might affect the speed and frequency of bursts of locomotor activity. Rain might terminate a quiescent phase in the beetles caused by the preceding drought. Finally, there may be a direct effect of rain on the locomotor activity, the effect of which on trapping captures was masked in the present study. Feeding, mating and egg-laying may also affect the amount of locomotor activity, and hence the number trapped; nor can the effects of human interference by such operations as hoeing, which disturbs the habitat of the beetles, be disregarded.

As a corollary of the fact that trap catches reflect activity, it can be assumed that locomotor activity was depressed during the fruiting period, since there was no increase in numbers trapped, yet soil sampling showed that the population was increasing. This could be due to adequate food or shelter, or both, in the form of the strawberries and the straw.

It is clear from the data presented, that numbers of beetles trapped cannot be used as an indication of population levels, and that the use of traps for carabid beetles should thus probably be reserved for qualitative purposes such as defining the period of activity. To define certain species as dominant because they are trapped most frequently (Skuhravý, 1959), is also open to criticism, since species which move more slowly, or less frequently, may be more abundant than others which on account of more frequent or rapid movement, are more readily trapped.

Acknowledgements

The author expresses his thanks to Dr. G. H. L. Dicker, who suggested the problem and supervised the earlier work, to his colleagues of the Statistics Section for advice, and to Mr. D. K. Brown and Mr. D. W. Jenner who assisted with the trapping.

Summary

Problems encountered in trapping *Harpalus rufipes* (Deg.), the strawberry seed beetle, and *Feronia melanaria* (Illig.), are discussed, and the relationship between climatic factors and numbers trapped is considered. Experiments in which trapping and soil sampling were carried out on the same plot are described and it was concluded that while numbers trapped were closely related to grass minimum temperature, they bore no relationship to the actual population present. Caution is therefore required in the interpretation of data from trapping experiments.

Reference

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PLANT PROTECTIVE CHEMISTRY

PHYTOTOXICITY TRIALS OF CERTAIN FUNGICIDES ON LANE'S PRINCE ALBERT APPLE

By A. H. M. KIRBY and MARGERY BENNETT

The use of the organic fungicide, captan, in place of lime-sulphur for control of apple scab has necessitated the concurrent use of another organic fungicide, based on 2:4-dinitro-6-(1-methylheptyl)phenyl crotonate (dinocap), to control powdery mildew; a report on the performance of dinocap, with and without captan, on several apple varieties has recently been published (1). During the same period, phytotoxicity trials were conducted on the sulphur-shy variety, Lane's Prince Albert, which can be grown as very convenient small bush trees that are easily sprayed and recorded.

Materials and methods

The trial was carried out in four seasons, 1953–56, on trees of Lane's Prince Albert on M.VII, planted as maidens in 1950/51 in two rows spaced at 8 × 6 ft. The trees were kept small by suitable pruning and their cropping had settled down by 1954.

Sprays were applied by hand-lance from either a small, self-propelled machine giving 60–100 lb/sq. in. pressure or a 50-gal. machine giving about 200 lb/sq. in. Screens were used to minimize drift as single-tree plots without guard-trees were necessary. Six replicates were available each year, the treatments being annually re-randomized within the blocks.

The materials used were as follows:

(*a*) a commercial wettable powder containing 25% of dinocap and related phenols;
(*b*) a commercial wettable powder containing 50% of captan.

The treatments comprised:

1. Dinocap at 0·05% active ingredients.
2. Captan at 0·1% active ingredient.
3. Dinocap at 0·05% active ingredients and captan at 0·1% active ingredient.
4. Unsprayed (control).

The rate for dinocap was the higher of the two rates used in the trial of fungicidal action (1), and the rate for captan was the one normally recommended for scab control, i.e. double that used in the other trial (1).

Five applications were made in each of the four seasons at the following times: (i) green-cluster; (ii) pink-bud; (iii) petal-fall; (iv) fruitlet; and (v) about 14 days after fruitlet stage. Only three applications (two pre- and one post-blossom) were made in the other trial (1).

Results

No damage to foliage was seen in any season, but petals of blossom remaining on trees receiving dinocap at petal-fall often showed marginal scorch, especially in Treatment (1) where captan was absent.

Tree to tree variation for fruit set and crop was still high in 1953, and there were no significant differences between treatments in that year.

In 1954, the percentage fruit set on Treatment 2 was almost double that on Treatment 1 which was about two-thirds that of the unsprayed control trees; set on Treatment 3 was also less than on the control trees, but variation was still too great for this to be significant at $P<0·05$. The same pattern emerged in 1955 and 1956, though differences were again too small to be significant. However, as the treatments were re-randomized each year, it was possible to analyse the results for the four years as one experiment, ignoring the unsprayed control trees which were not strictly comparable after the first year. This analysis showed that there were very highly significant differences between the means for the four years ($P<0·001$) (Table I).

These results were confirmed by the numbers of mature fruit (August counts) per 100 fruit buds in the second, third and fourth years; the differences were not significant in 1954 or 1956, but in 1955 the percentages on Treatments 2 and 3 were significantly higher ($P<0·05$) than on Treatment 1.

TABLE I

MEAN VALUES FOR SET FRUIT AS PERCENTAGE OF FRUIT BUDS FOR THE FOUR SEASONS, 1953–56

	1 Dinocap 0·05%	2 Captan 0·1%	3 1+2	4 Unsprayed control
1953	78·3	101·9	90·7	124·3
1954	46·2	84·3	59·6	(74·1)
1955	37·2	66·8	48·7	(58·0)
1956	61·5	89·2	77·7	(63·8)
Mean (S.D. 6·4 at P<0·05)	55·9	85·5	69·2	—

Moreover, taking the three years together, the percentage of fruit bud yielding mature fruit was significantly lower (P<0·05) for Treatment 1 than for either of the other Treatments (Table II).

TABLE II

MEAN VALUES FOR MATURE FRUIT (AUGUST) AS PERCENTAGE OF FRUIT BUD FOR THREE SEASONS, 1954–56

	1 Dinocap 0·05%	2 Captan 0·1%	3 1+2	4 Unsprayed control
1954	37·8	40·9	40·2	(31·4)
1955	28·8	41·5	43·5	(44·7)
1956	38·0	52·4	49·0	(33·4)
Mean (S.D. 8·3 at P<0·05)	34·9	44·9	44·2	—

Crop numbers and weights were low in 1953 but increased on all trees during the four seasons. In 1954 and 1955, the figures followed those of the mature fruit percentages given in Table II, both number and weight for Treatment 2 exceeding those for Treatment 1 by about 50%, though variation from tree to tree was too great for this to be significant at P<0·05. In 1956, crop weights on Treatments 2 and 3 were very similar, that on Treatment 1 being actually higher, though the percentage fruit set had been lower (Table I). However, trees receiving Treatment 1 had borne nearly twice as many fruit buds as those receiving Treatment 2 and the reduction in set was insufficient to offset this advantage.

Lane's Prince Albert is not prone to russeting of the fruit, and little of this trouble was found on any of the treatments in 1953 and 1954. In 1955, however, there was rather more russeting on all treatments, stalk-end russet being more prevalent than side russet. There was a further increase of both types of russet in all treatments in 1956, and the percentage of fruits displaying stalk-end russet was significantly higher (P<0·05) on Treatment 1 than on Treatments 2 and 3 (Table III).

TABLE III

MEAN PERCENTAGE FRUITS BEARING STALK-END RUSSET IN 1956

	1 Dinocap 0·05%	2 Captan 0·1%	3 1+2	4 Unsprayed control
(S.D. 7·05 at P<0·05) ..	28·2	18·9	21·0	(21·9)

There was no evidence in this trial that captan, at 0·1%, reduced the normal incidence of russeting on this variety.

Discussion

In spite of the relatively high cost of materials, disease control on apple with a combination of captan and dinocap has become widespread, and the threat offered by apple mildew has been contained. From a three-year study on two dessert and two culinary apple varieties, Moore *et al.* (1) concluded that a mixture of dinocap at 0·025% and captan at 0·05% was safer on the sulphur-shy varieties, Cox's Orange Pippin and Newton Wonder, but of less advantage on other varieties such as James Grieve or Bramley's Seedling. When the rate for dinocap was increased to 0·05%, these workers found significantly increased russeting on James Grieve as well as on Cox's Orange Pippin, but the addition of captan, even at 0·05%, almost nullified this effect ; curiously enough, with 0·025% dinocap the degree of russeting was hardly affected by adding captan. Fruit set and mature fruit were reduced in all years on Bramley's Seedling, and in one year on James Grieve ; the crop weights were also reduced, but the reductions were not significant.

A consistent reduction of fruit set was found in the experiments on Lane's Prince Albert where dinocap was applied at 0·05%. This reduction was less obvious by August of each year and was not significant by harvest, as compared with data from trees receiving captan alone. When the two chemicals were applied together, the percentage set was intermediate between those for the two chemicals applied separately ; the mature fruit percentages and the crop weights were much nearer those for the trees sprayed with captan alone. Few differences emerged for russeting, the one significant difference being found in 1956 when dinocap caused more russet than captan or captan plus dinocap.

There is therefore evidence from these experiments, as well as those of Moore *et al.* (1) that the margin of safety for dinocap on some apple varieties is not large, and that the use of this fungicide for mildew control is much safer when captan is applied at the same time, even at half the rate recommended for scab control.

Summary

Trees of the apple variety Lane's Prince Albert, on M.VII, were sprayed twice pre-blossom and thrice post-blossom during four successive seasons with dinocap (2:4-dinitro-6-(1-methylheptyl)-phenyl crotonate ; DNOPC), or captan, or both.

Dinocap, at 0·05%, caused consistent reduction of fruit set and mature (August) fruit as compared with captan alone ; dinocap plus captan was intermediate in effect on fruit set, but mature fruit and picked crop were very similar to those for captan only. More stalk-end russet was caused by dinocap alone than by the other two treatments in 1956, but not in the preceding three seasons.

The conclusion is drawn that the addition of captan to enhance scab control also confers a wider margin of safety where dinocap is used for control of apple mildew.

Reference

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HARVEST RESIDUES OF MALATHION ON SOFT FRUITS AND APPLES

By R. P. TEW and JOAN M. SILLIBOURNE

Malathion, *S*-1:2-di(ethoxycarbonyl)ethyl dimethyl phosphorodithioate, is a relatively non-persistent contact insecticide of low mammalian toxicity. It has in the past been used on fruit as an aphicide but in recent years other potential uses in this field have arisen, particularly as a consequence of its safety and non-persistence. Its value against the raspberry beetle, *Byturus tomentosus* Fab., on *Rubus* spp. and to a less extent against the strawberry seed beetle, *Harpalus rufipes* (Deg.) has recently been investigated at this Station. In 1959, when, as a consequence of the hot dry summer, the second generation of codling moth caused more extensive damage than usual to apples in August, it was fairly widely used against this pest. At present a minimum interval of seven days between application to any growing edible crop and harvest is officially recommended (1). Although this period of time is unlikely to be infringed in any of the new uses of malathion mentioned above, it was considered desirable to measure the harvest residues to confirm its safety to the consumer.

Analytical methods

The insecticide was recovered from the fruit (raspberries in 1958, loganberries and apples in 1959, strawberries in 1960), by extraction with carbon tetrachloride. The malathion was determined by the method of Norris *et al.* (2), essentially unmodified. In each case, calibration graphs were prepared using solutions of the insecticide in a carbon tetrachloride extract of unsprayed fruit from the appropriate crop, and colours were measured with the ' Spekker ' absorptiometer (Filter No. 601) using cells with a 4 cm path.

Experiment in 1958

Samples were collected from a trial in which fruiting raspberry canes (var. Lloyd George) had been sprayed on a single occasion (3rd July) with one of three concentrations (0·1%, 0·05% and 0·025%) of malathion emulsion, containing 0·0125% sodium dioctyl sulphosuccinate, and applied by conventional, power-operated, hydraulic spraying equipment. Samples, each of 800 g of fruit, were collected at ' peak-pick ' (11th July, i.e. 8 days later) from each of these treatments and from the control. Each sample was shaken in a 3 kg glass bottle with 800 ml of a 10% solution of acetone in carbon tetrachloride for 3 hr and allowed to stand overnight. The liquid layers were then decanted into a separating funnel and the carbon tetrachloride extract run out into a graduated cylinder to measure its volume. This extract was washed with two 100 ml amounts of distilled water and dried with sodium sulphate. The volume was restored with more carbon tetrachloride to the value recorded before washing and suitable aliquots were taken for analysis (Table I).

TABLE I

HARVEST RESIDUES FOR RASPBERRIES IN 1958

Concentration applied (%)	Harvest residue (p.p.m.)
0·025	0·18
0·05	0·37
0·10	0·94

Experiments in 1959

Loganberries

Samples were collected from a trial in which the insecticide had been applied to loganberry canes at three concentrations 0·025%, 0·05% and 0·10%, each concentration being applied twice (10th and 22nd June). In addition, the middle concentration had been applied once only on either the first or on the second occasion. These sprays again contained 0·0125% sodium dioctyl sulphosuccinate and were applied by conventional hydraulic equipment. Samples, each of 500 g, were

collected at ' peak-pick ' (29th June) and were shaken for 3 hr with 500 ml of 10% acetone in carbon tetrachloride and allowed to stand overnight. The decanted extract was washed and dried as described above, and analysed (Table II).

TABLE II

HARVEST RESIDUES FOR LOGANBERRIES IN 1959

Treatment	Residue (p.p.m.)
0·025% on 10.6.59 and 22.6.59	0·09
0·05% on 10.6.59 and 22.6.59	0·26
0·10% on 10.6.59 and 22.6.59	0·49
0·05% on 10.6.59 only	nil
0·05% on 22.6.59 only	0·16

Another trial on loganberries was undertaken in 1959 to study the rate of decay of malathion deposits. A single application of 0·05% emulsion and 0·0125% wetting agent was made on 29th June and fruits were collected for analysis the same day and 2, 4 and 7 days later. Processing and analysis were as before ; in addition, determinations were made by the microbioassay procedure using *Drosophila* (3) (Table III).

TABLE III

RATE OF DECAY OF MALATHION DEPOSITS ON LOGANBERRIES

Time interval from spraying	Residue (p.p.m.)	
	Chemical method	Micro-bioassay
4-hour sample	10·6	8·2
2-day sample	4·2	2·6
4-day sample	1·3	1·2
7-day sample	0·7	0·5

Apples

Malathion at 0·075% was applied hydraulically, under conditions representing commercial practice, to Ellison's Orange apple trees on 14th August. Samples were collected on that day and after the elapse of 1, 3 and 6 days. The insecticide was recovered by immersing the individual fruits comprising each sample in two successive, adequate quantities of warm carbon tetrachloride. Analysis was by the method described above and the results obtained were as follows :

TABLE IV

RATE OF DECAY OF MALATHION DEPOSITS ON APPLES

Time interval from spraying	Residue (p.p.m.)
Initial sample	1·96
1-day sample	1·09
3-day sample	0·66
6-day sample	0·28

Experiments in 1960

Strawberries

An emulsion containing 0·1% malathion and 0·0125% sodium dioctyl sulphosuccinate was applied to fruiting Cambridge Favourite strawberry plants on 30th June. Samples were taken immediately after spraying and 2 and 6 days thereafter. These were processed and analysed as described above (Table V).

TABLE V

RATE OF DECAY OF MALATHION DEPOSITS ON STRAWBERRIES

Time interval from spraying	Residue (p.p.m.)
Initial sample	13·4
2-day sample	4·9
6-day sample	0·5

Discussion

The harvest residue data on both raspberries and loganberries collected from the entomologists' field trials of biological efficiency of malathion show the relationship between spray concentrations and spray residue which has frequently been observed. In the 1959 trial on loganberries it is obvious that the main contribution to the harvest residue was from the second of the two sprays applied seven days before picking. The initial deposit on apples was considerably lower than would be expected from complete cover from 0·075% malathion. Nevertheless, the data for persistence on apples and on both loganberries and strawberries (Fig. 1) indicate a very short half-life (1·5–2 days) for malathion.

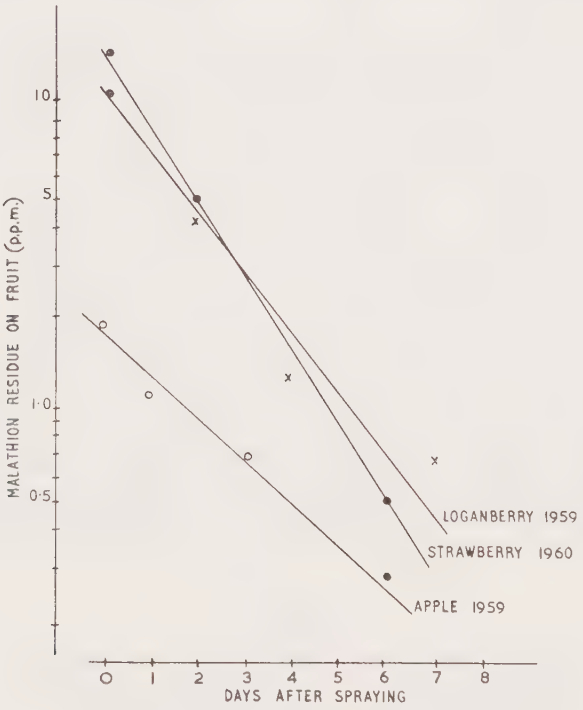

FIG. 1

Persistence of malathion on fruit

The very low harvest residues within a day or so of spraying at economic levels confirm the comfortable margin of safety provided by a seven day minimum interval ; all figures were, in fact, well within the tolerance of 8 p.p.m. permitted in the U.S.A.

Summary

Lloyd George raspberries, sprayed with malathion emulsion at up to 0·1% active ingredient a week before harvest, were found to carry less than 1 p.p.m. malathion at harvest.

Loganberries similarly sprayed twice, at 19 and 7 days before harvest, were found to have less than 0·5 p.p.m. at harvest.

Cambridge Favourite strawberries, sprayed with 0·1% malathion were found to have less than 1 p.p.m. one week later.

Rate of decay studies on loganberry, strawberry and apple show that the half-life of malathion is only 1·5–2 days and that applications at the rates recommended for control of codling moth on apple, even late in the season, are unlikely to leave residues exceeding 0·5 p.p.m. on fruits picked a week after spraying.

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FRUIT STORAGE INVESTIGATIONS

OBSERVATIONS ON CELL SIZE AND NUMBER IN RELATION TO FRUIT SIZE IN APPLES

By M. PATRICIA DENNE

It has been suggested that the storage quality of apples from different treatments may be associated with differences in the cell size. Martin and Lewis (4) showed that fruit from trees carrying a light crop had larger cells, and poorer keeping quality, than apples from trees with a heavy crop. On the other hand, in a thinning trial at this Station fruit size appeared to be related to storage quality, but was not associated with differences in cell size.

Differences in fruit size within a tree are also related to differences in storage quality. Bain and Robertson (1) showed that such variations in fruit size were due to differences in cell number rather than in cell size, though there were indications that the smallest fruit had smaller cells.

It was therefore considered desirable to find out how fruit size is related to cell size and cell number in apples grown on this Station. This paper reports developmental observations on apples of various sizes from the same tree, on apples from trees carrying different amounts of fruit, and on apples from trees thinned after the June drop.

Materials and methods

Samples were collected from a group of 32 eight-year-old dwarf pyramid trees of Cox's Orange Pippin on M.VII. The cell number was determined by counting the number of cells across the cortex at the equator of the apples, counting from the epidermis to the petal and sepal vascular bundles and taking the mean of 16 counts from each fruit. The diameter of the cortical cells was calculated from $\frac{\text{mean distance across cortex in mm}}{\text{mean number of cells across cortex}}$.

The apples for investigating the variation in fruit size within a tree came from six trees with a moderate crop; the five heaviest fruits were selected from each tree, together with the ten fruits nearest to the mean fruit weight on each tree, and the five lightest fruits.

All the trees appeared to be in an 'on year' condition before flowering, but on many trees the blossom failed to set, with the result that the final crop varied in amount. At harvest, six trees had only a few apples (under 10 fruits per tree), five trees had rather more (20–29 fruits per tree), and five trees had a moderate crop (50–69 fruits per tree); a composite sample of 10 fruits was collected from each of these groups of trees for cell size and cell number determinations, selecting the fruit nearest to the mean fruit weight from each tree. The fruit diameter was measured at 2–4 week intervals from early June until harvest; 60 fruitlets were measured at random on each tree during June (or all the fruitlets on trees having less than 60), and 40 fruitlets at random during July and August.

Six trees were thinned after the June drop, on 13th July 1959. It was hoped that this late thinning might result in an increase in cell size rather than in cell number, as cell division was likely almost to have ceased by this time (2). Six trees with a similar crop were left unthinned as controls. On the thinned trees, 1 medium-sized fruitlet was selected on each branch having 6 or more closely-spaced apples, and all the other fruitlets on the tree were removed. Similar fruitlets on the unthinned control trees were selected and labelled. The diameter of the fruitlets was measured at about fortnightly intervals from 10 days after thinning until harvest.

Results

Variation in fruit size within the tree

Cell size.—Fig. 1 shows the mean cell size in small, medium and large fruit from the six trees. Although there was considerable variation in cell size between fruits of similar size, there was a relation between cell size and fruit size ($P < \cdot 001$). There was a greater difference between the cell size of small and medium fruit than between that of medium and large fruit.

Cell number (Fig. 2).—There appears to be a fairly close relation between fruit weight and cell number. Compared with the medium-sized fruit there were proportionately more cells in the

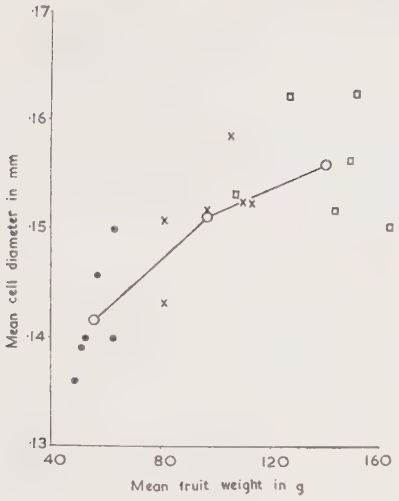

FIG. 1

Relation between cell size and fruit weight within a tree

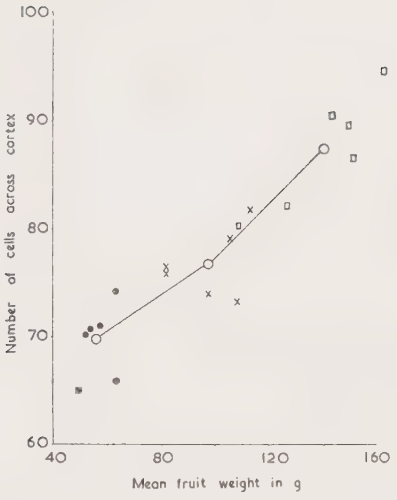

FIG. 2

Relation between cell number across cortex and fruit weight within a tree

● mean of 5 small fruit
× mean of 10 medium fruit
□ mean of 5 large fruit
} from individual trees
–O– mean of 6 trees

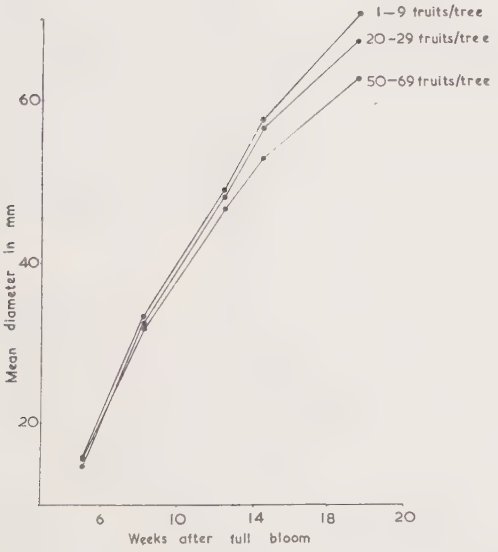

FIG. 3

Effect of amount of crop on fruit diameter

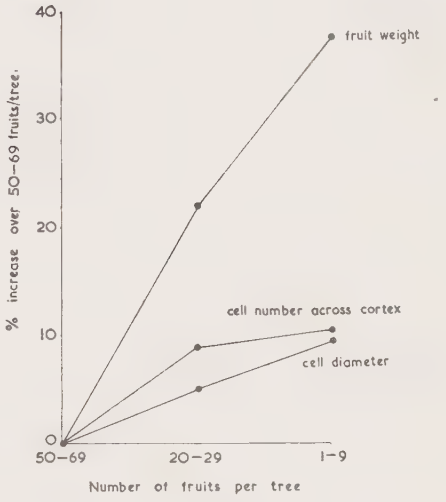

FIG. 4

Effect of amount of crop on fruit development

larger fruit than in the smaller, an effect that is more marked in fact than is apparent from the diagram, because the total number of cells increases proportionately more than the cell number counted across the cortex.

The effect of amount of crop on fruit development

Fruit diameter (Fig. 3).—The diameter of fruit from light crops increased more rapidly than that of fruit from heavier crops. This trend was apparent 8 weeks after full bloom, although this was not significant at the 5% level, until 12 weeks after full bloom.

Fruit weight, cell size and cell number (Fig. 4).—There was a wide range of fruit weight within

a tree and between trees, but in general the mean fruit weight was inversely proportional to crop size. Both cell number and cell size increased with fruit weight as the crop size decreased.

The effect of late thinning on fruit development (Table 1)

The thinned fruits tended to be larger than the unthinned by the time of the first measurement, 10 days after thinning, and this difference had increased slightly 14 days later ; there was little if any subsequent divergence in the rate of growth. Table 1 shows that the fruits from the thinned trees were larger and heavier ($P<\cdot05$) at harvest than the unthinned controls ; this was largely due to an increase in cell number ($P<\cdot01$). There was also a slight increase in average cell size, but this did not reach significance at the 5% level.

TABLE I

THE EFFECT OF THINNING AFTER THE JUNE DROP ON THE DEVELOPMENT OF COX'S ORANGE PIPPIN APPLES

	Mean diameter in mm			Means at harvest		
	10 days after thinning	24 days after thinning	At harvest	Fresh wt of fruit in g	Cell no. across cortex	Cell radial diameter (mm)
Thinned	48·27	55·09	66·24	115·17	83·30	·151
Unthinned (Control) ..	46·53	52·49	62·58	100·40	75·46	·147
% increase over control	3·7	5·0	5·8	–	–	–

Discussion

Variation in fruit size within a tree appears to be related to differences in both cell size and cell number ; the larger fruit tended to have more cells and slightly larger cells than the medium-sized fruit, while the smaller fruit had fewer and considerably smaller cells than the medium-sized fruit. The relationship between cell division, cell expansion, and fruit size probably depends on the predominant factors affecting fruit development on each tree, in the particular season.

The trees bearing a few fruits had larger and heavier fruits than those with more fruits ; the size of the crop affected both cell division and cell expansion in the fruit cortex.

The fruits from trees thinned after the June drop tended to be somewhat larger than fruits from the control trees 10 days after thinning, and there was little difference in the rate of growth from 24 days after thinning until harvest. This suggests that the effect of thinning operated mainly in the following few weeks, a finding that agrees with the work of Magness, Overley and Luce (3), who observed that fruit thinned when the June drop was nearly over showed a size difference between treatments shortly afterwards.

The cell number determinations suggest that cell division was stimulated by late thinning. Although it is commonly accepted that cell division in the apple fruit ceases within a few weeks of pollination, there is evidence to show that it may continue at a slow rate for several months, and it was found to continue almost until harvest in some early-thinned fruitlets of Miller's Seedling (2).

Summary

1. Variations in fruit size within a tree were found to be related to both size and number of cells in the cortex.

2. Differences in fruit size between trees carrying different numbers of apples were also related to cell size and number.

3. Late thinning appeared to increase fruit size by increasing cell number during the first few weeks after thinning. There was probably also an effect on cell size.

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Part IV

BULLETINS FOR FRUIT GROWERS

FRUIT GROWING IN NORTHERN ITALY

By A. P. PRESTON

The primary object of this tour was to see the actual growing conditions and methods of culture in the important fruit areas of northern Italy. The tour was made during the latter part of June and July so that cropping trees could be seen of all but the earliest varieties of apples and pears. No special attention was given to packhouse layout and details of marketing, since these points had been covered by representatives of the Kent N.F.U. Fruit Committee in 1959.

About 80% of the apples and pears produced in Italy are grown on the extensive and fertile plain of the River Po east of Milan, the outstanding area being that surrounding Ferrara. A further 15% comes from the Alto-Adige in the south Tyrol, north of Trento, comprising the Adige Valley and its associated valleys Val di Non and Val Venosta. Some of the earliest Williams' Bon Chrétien pears come from a small area near Pescara beside the Adriatic.

Administratively, Italy is divided into Provinces, each one having members of the government inspectorate stationed at its administrative centre. These officers give help in improving the standard of culture and orchard hygiene, and in tackling drainage and pathology problems. They are probably the equivalent of the N.A.A.S. regional specialist officers. Most fruit growing districts have one or more *consortzioni* ; these are organizations of the growers by the growers, and in each area they employ one or more assistants who keep in close touch with growers by visits, demonstrations and talks ; they are quite independent of the government inspectorate. A *consortzione* also gives assistance in forming new co-operatives and supplies market intelligence. At one *consortzione* near Verona 55 farmers co-operate. The fruit stores and packhouses, *magazines*, may be either privately or co-operatively owned.

The over-riding controlling body governing the quality of exports from Italy, whether they are apples or shoes, is the I.C.E. (Italian Foreign Trade Institute). The uniformly good-looking fruit exported from Italy provides an excellent example of the thoroughness with which the I.C.E. officers carry out their work.

Alto-Adige

Adige Valley

This is one of the oldest fruit areas in northern Italy. From the south, the Adige Valley is entered through a narrow gorge a few miles north of Verona and it varies in width from a few hundred yards to 4 or 5 miles. On either side of the fast-flowing Adige is a dark rich soil bounded by steep slopes leading to dolomitic limestone mountains. Northwards as far as Trento the valley floor is mainly planted with vines, but farther on vines have been replaced by fruit, mainly apples and pears, with a few vineyards left on the steep slopes. The whole area is therefore very susceptible to radiation spring frosts and severe ones occur every 2 or 3 years. This year there were five severe frosts in succession. Since 1952 water sprinkling has become more and more popular as a method of frost protection and it is now exceptional to find a holding without it. The sprinkler masts are 5 metres high on a 24 metre grid and use pumped water.

Holdings in the Adige Valley vary in size from a few acres up to about 30 and are, in the main, owner occupied. The land is very expensive. Climatic conditions in the area are interesting ; air currents over Lake Garda and the warm valleys meet those of the Alps, and storms with hail are fairly frequent. The Adige Valley and the Val Venosta are sheltered from the heaviest rains, characteristic of more northern valleys, by the mass of the Alps. Also, these open valleys are warmer, especially at mid-day. Due to the mountains on either side, however, the effective sunshine hours are less than one would suppose. The relatively cool nights and warm days, together with a high summer rainfall, probably assist production of high colour on apples. Now that frost damage can be largely prevented, hail presents the greatest risk in the area. The firing of rockets to destroy the hail-forming nuclei is claimed to give moderate success—nevertheless, several orchards showed severe damage this year.

Clonal rootstocks are almost non-existent in the area. There is a trial in the Trento district, under the supervision of Professor Breviglieri, in which apples on seedling rootstocks are compared with those on M.IX, M.II, M.VII, M.XI, M.XIII and M.XVI. A few growers were trying odd rows of trees on M.VII and M.II. Seed of the pear (Kirchensaller Mostbirne) and apple (Bittenfelder) rootstocks comes from Germany, there was considerable patchiness in germination and variation in the seedling rows. Non-clonal St. Julien was being used as a rootstock for apricots and a wild apricot, Millionaire de Meinz, is being tried. The land is said to be too wet for quince rootstocks as there is a fairly high water-table. I saw no serious dieback and waterlogging does not appear to be serious. Little trouble has been experienced in replanting on this rich soil ; the soil is banked and a tree is planted on the mound.

Fig. 1
Map showing the main fruitgrowing and nursery areas of northern Italy

About 20% of the fruit consists of pears, mainly Williams' Bon Chrétien and Beurré Bosc ; the Williams' ripen 7-10 days later than in the Ferrara province. Green Summer Magdalena pears were being picked and sold locally (28th June). Excellent crops of Precoce di Trevoux were seen on trees 25 to 30 ft high. Pears are usually left unpruned for seven or more years before being shaped-up ; they make large trees with a centre leader from which radiate cropping laterals, and doubtless the very heavy crops offset the extra cost of picking such tall trees. No Conference trees were seen.

The older apples are mainly Kalterer, Champagne, and Gravenstein. Magnificent Kalterer trees, more than 40 years old, were cropping heavily ; this apple will store for 10 months and apparently is fairly hail resistant. There is a general policy of replanting old fruit with newer varieties such as Jonathan, Golden Delicious, and Rome Beauty. As with pears, the leaders of many of the young apple trees had never been pruned. They were planted at 5 metres square. There was considerable russeting on fruits of Golden Delicious, mainly on the outside of the tree, and many explanations were offered, including lime-sulphur or parathion sprays, too rich a soil, spraying in mid-day sun, and too large a spray droplet. A young plantation of Cox's Orange Pippin was just surviving ; experience with this variety has not been happy. In Trento, farther down the valley, a plantation of Cox trees looked much better. They were carrying a moderate crop, but the fruit was badly russeted and cracked, and here, too, rich land was blamed. Cox ripens on the tree in late August ; Beauty of Bath were being picked (28th June).

Some growers were using automatic sprayers but the majority were using, and preferred, hand lances maintaining that these gave better cover. Scab can be bad in this area with a high summer

rainfall, and a total of 20 sprays for apples and 10 for pears are often applied. Copper is frequently used pre-blossom and either ziram or zineb post-blossom. Captan was little used, probably because there was no propaganda for it, unlike karathane which was freely advertised on hoardings in Bolzano and Merano. Two sprays of parathion were used for codling moth. Serious damage to mature trees had been caused by larvae of the May bug eating roots and inducing premature defoliation.

The general impression of the Adige Valley is one of luxuriant growth and the use of heavy cropping varieties. The rich soil allows of rough treatment by English standards, for example, grass and cow parsley 2-3 ft high is quite common ; this may be cut once or twice a season. Frequently a hay crop is taken from between the fruit trees.

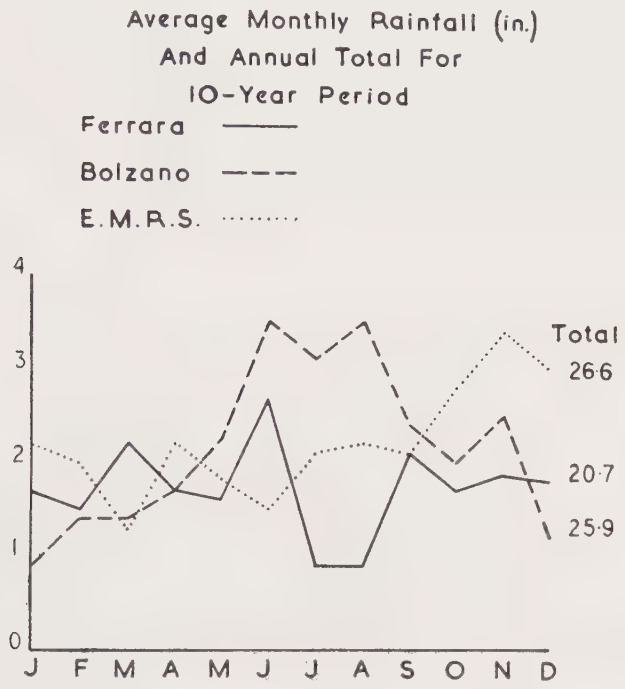

FIG. 2

Distribution of rainfall for Ferrara (Plain of the River Po), Bolzano (Adige Valley), and East Malling

Val di Non

Running almost parallel with the Adige Valley and about 10-20 miles west of it is the Val di Non area. The River Noce which runs through the area has recently been dammed for an hydro-electric power scheme. Some 30 or 40 years ago it was a subsistence farming area, the smallholders, with about 5 acres each, growing maize and potatoes for home use. Now it is a highly cultivated fruit area. The degree of communal effort by the growers is most impressive and the helpful advice given by the inspectorate results in uniformly well-produced fruit. For example, there are communal reservoirs and spray-mixing tanks which localize poisons, minimizing the risk of harm to peasants. Orchard boxes, implements and even tractors are assembled in the area. A growers' federation raises trees and these are planted as 5-year-olds after careful lifting by a monkey winch ; thus the growers are able to have their land in production within a year or two of planting. It is hoped that an official certificate may soon be supplied each year before harvest, certifying freedom from harmful spray residues as an aid to selling. The fruit is collected and stored co-operatively but merchants come and buy, unlike the Adige area where the co-operatives pack and sell direct.

Reinette du Canada is the main apple grown ; it will keep from October to May and is sold mainly in Italy and France. New plantings include Golden Delicious but this variety is said not to do well above the 500 metre level. Louise Bonne and Pastorenbirne pears are grown, also some Beurré Bosc and Conference. Conference seems to do better on the higher land. Fruit is also gradually replacing vines as in the Adige area, but there is chalk here and cases of chlorosis on both vines and apples were seen. In the valleys of the Italian South Tyrol there are about 25,000 acres of fruit.

Plain of the River Po

This area is scenically uninteresting, unlike the beautiful Adige Valley, but agriculturally it is of exceptional interest. Large-scale drainage schemes over more than a century have rendered this one of the most fertile agricultural areas in the world. The principal fruit-growing regions are along the eastern part of the plain and fairly close to the Adriatic in the provinces of Bologna, Ferrara, and Ravenna. Perhaps the most interesting area surrounds Ferrara where there are about 100,000 acres of fruit, the fruit having steadily ousted hemp as the most important crop. Many new plantations have been established since the last war and development is continuing. Spring frost damage is not a serious problem since the plain is so broad and the Adriatic relatively near. Spring temperatures are particularly favourable for fruit growing, especially pears. The long growing season, with fairly high mean temperatures, and a moist soil, are ideal for those fruits that require warmth, as for example, peaches, apples of the Delicious group, and Passe Crasanne pear. In July and August it is dry, in contrast to the Adige Valley where late summer rainfall is fairly high.

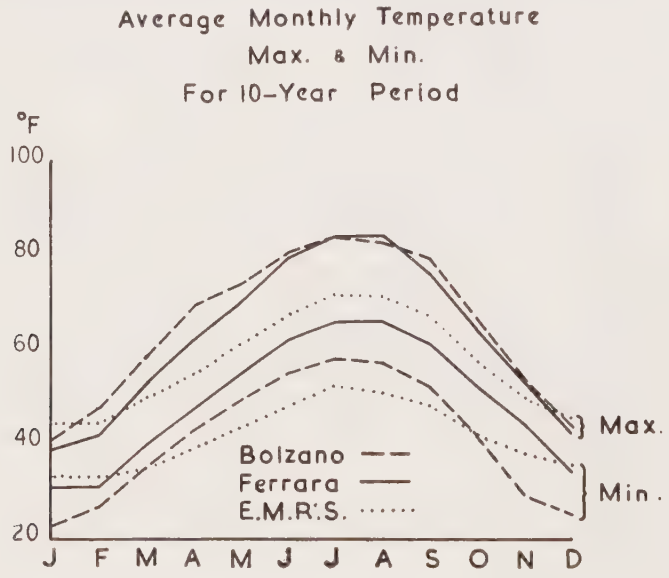

Fig. 3

Distribution of maximum and minimum temperatures for Ferrara, Bolzano, and East Malling

Ferrara

Signor Bonvicini pioneered commercial fruit growing on the Po Plain when, in 1904, he established orchards at Massalombarda, between Ravenna and Ferrara. Rapid development took place in this area between the two world wars, especially in the 1930's. Many orchards were neglected during the last war and San José scale became a major pest ; this has now been cleared up. Much of the fruit is grown under a landlord and tenant system known as the *mezzadria*. The landlord provides the land, buildings and trees, and the tenant with his family provides the labour, machinery, sprays and manures ; the income from the crop is then shared between landlord and tenant.

The water-table in the Ferrara area is some $1\frac{1}{2}$-3 ft down in winter, falling to 6-9 ft in summer. Irrigation is seldom necessary on this fertile loamy soil. Rockets were being used against hail in this area also, but damage to fruit this season was severe.

In Ferrara one is struck by the great variety of tree shapes, especially with apples, and often within a single farm. Original bush plantations now give the impression of fruit being grown in closely pruned hedgerows. Some trees were of the centre-leader type, others open-centre, with no more than 3 or 4 primary branches and no secondary framework branches. With some mature centre-leader trees the branches arose in distinct whorls. Trees in many of the older orchards had been trained as espaliers and were 12-15 ft high and closely pruned. On some farms even the ' hedges ' bordering the public road were of clipped apple trees in full production. Many orchards were overcrowded and fruit colour must suffer on this account. All orchards were clean cultivated and young ones were intercropped with strawberries, maize or other agricultural crops. Peaches are thinned by hand but apples and pears are not thinned.

Fig. 4
Adige Valley showing intensity of tree fruit planting on the valley floor. River Adige flows across the picture

Fig. 5
Adige Valley. Water sprinkler masts in position for spring frost protection

Fig. 6
Ferrara. Red Bartlett trees on *Pyrus betulaefolia*, 4-year-old, grown as free palmettes

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FIG. 7
Ferrara. Golden Delicious on M.IX 5 years from planting, grown as free palmettes

FIG. 8
Trento. Newly set trees in high grass for hay

FIG. 9
Hail prevention. Iron tube set in the ground to hold the rocket

Almost all the younger plantations of pears, and many of apples, were being grown as free palmettes (a type of espalier), on seedling apple and pear rootstocks, Provence and Angers quince rootstocks, and M.IX. Newly established areas of Japanese plums (var. Shiro) on Myrobalan seedlings were also being trained on this system and were cropping in their second year. The method has been developed from the research work of Professor Dotti in the 1930's who recommended the bending of branches rather than their removal by pruning. Briefly, a maiden tree is planted against two 8 ft bamboo canes held in the ground in the form of a St. Andrew's cross ; two parallel wires may be needed later to run horizontally down the rows and to which the canes may be tied. The centre leader is tipped each year to ensure a supply of lateral branches and these are tied down with willows to the canes and wires in non-vertical positions. Very little other pruning is done, as many shoots as possible being tied in and only very vigorous or awkward ones being cut away. Heavy crops of well coloured apples and pears were seen on 4-year-old trees pruned by this method. It is easy to pick the fruit and to work between the rows.

Abbondanza, well known to English buyers as a highly coloured apple with a tough skin and poor flavour, is not much planted now. The main apples in the newer plantations are those of the Delicious group, and Rome Beauty, Jonathan, Winesap and King David. The very early American apple Close is being planted and is reported to ripen in mid-July. Russeting on Golden Delicious was also bad in this area. Again, Cox was reported to ripen too early and to crack badly and it was discontinued on many farms 10 years ago.

Pears in the Ferrara district are mainly Kaiser Alexander, Coscia, Williams' Bon Chrétien, Red Bartlett, Passe Crasanne, Précoce de Trévoux, Comice and Abbé Fétel. Some growers have tried Conference but they do not think it a heavy enough cropper, and Kaiser Alexander, which resembles Conference, is more popular. Mme. Moutot and Souvenir de Charles strawberries are used as intercrops, the rows often being allowed to become matted beds. On one holding cropping bushes of black currants, flanked on either side by nursery pear trees, were the intercrops between pairs of rows of free palmette plums.

Ferrara is the foremost apple area on the Plain of the River Po, and the luxuriant growth and heavy crops were most impressive.

Ravenna

Ravenna is mainly a peach growing area, apples and pears being secondary. However, in some districts, at Massalombarda for example, the soils have become peach ' tired ' and the orchards are being replanted with pears.

The inspectorate at Ravenna have a field station where there are trials of clonal and seedling apple rootstocks, pear and quince rootstocks, apricot and plum variety trials, and a trial of different pear intermediate stem-pieces. New pear varieties raised by Professor Pirovano in Rome were also under trial ; some of these looked most promising, others were showing severe chlorosis. The pear Abbé Fétel seems to be particularly sensitive to iron deficiency. Young apricots and plums had been planted to form free palmettes, and maize planted as an intercrop was towering above the newly set trees.

Soil waterlogging is frequent in the Ravenna area. This year there was considerable dieback and death of whole trees, attributed to the exceptionally wet autumn last year.

Vignola

Although not geographically on the Plain of the Po, Vignola is a most important sweet cherry centre lying on the lower slopes leading to the Apennines. From this area comes the bulk of the early black short-stalked bigarreau cherries. The trees are large, on seedling rootstocks, and mainly in grass. An efficient refrigerated rail car service takes the crop to importing countries. Other centres of cherry production are at Cesena, near Rimini, and in the Verona province. Bacterial canker seemed troublesome at Cesena.

Verona Province

The city of Verona is an important agricultural centre and claims the largest refrigeration plant in Europe. The district, through which the Lower Adige flows, is primarily a peach growing area. Clay zones in the soils around Verona cause serious waterlogging which often kills peach trees. Peaches make exceptional growth, 4-year bushes may be 8-10 ft tall, but are relatively short-lived lasting only 12-15 years. As at Ravenna, replanting is a problem but pears do well and Verona may become as important for pear production as it is at present for peaches. Most peach trees are grown as open-centre bushes and older ones receive pretty drastic winter pruning, but very few cases of silver leaf

were seen. A severe hailstorm had damaged the branches of peach trees in much the same way as occurred with apples in the Kirdford and Brenchley areas two years ago.

In spite of what would appear to be an adequate rainfall, the high evaporation rate makes irrigation essential ; this is mainly done by the furrow method but many growers are installing overhead irrigation systems. With overhead irrigation, small amounts and slow application rates are used, i.e. $\frac{3}{4}$ in. of water in about 10 hours.

Young pear plantations were being trained almost entirely in the free palmette form. The main varieties grown are Coscia, which was just ripening (4th July), Santa Maria and Butirra Précoce (both new Morettini seedlings from Coscia × Williams'), Williams' Bon Chrétien, Dr. Jules, Précoce de Trévoux, Kaiser Alexander, Abbé Fétel, Passe Crasanne and Comice. Beurré Giffard is also grown on some holdings.

New apple plantings in the area consist of the same varieties as those already mentioned for Ferrara. They were planted in rows 30 ft apart and 10 or 12 ft apart in the row with provision for one tree-thinning. The rows were intercropped with soft fruit, maize, and in some cases hay. Most of the older apple orchards comprised bush trees with three main boughs, the laterals being either renewal-pruned or regulated. Many older trees are being top-worked to newer and more profitable varieties. Ten years ago 90% of the apple crop consisted of Abbondanza but now this has been reduced to 40% by top-working and new plantings. Frameworking was not seen in any of the areas visited.

Strawberries are grown as spaced plants and in matted rows, usually as an intercrop between peaches. The main varieties are Mme. Moutot, Regina, Souvenir de Charles, Perle de Prague, and the Senga varieties. A plot under the control of the inspectorate had under test Royal Sovereign, Climax (without Yellows), Huxley, Esplanade, St. Joan, Talisman and Liberation d'Orleans. Griseofulvin had given good results in controlling Botrytis but it was too expensive, and at present one autumn and two spring sprays of captan are being tried. Regina seems more resistant to this disease than does Mme. Moutot. Black polythene sheets laid between the strawberry rows had resulted in fewer weeds, extra vigour, precocity, and higher cropping than on untreated beds ; the polythene sheets had, however, the disadvantage of increasing runner production. Strawing is not practised as it is too expensive. The beds are kept for three cropping years and they are irrigated once a week from mid-April to mid-September.

Black currants are still a new crop with growers but excellent growth was seen on 4-year-old bushes of Goliath, Triple X, Hilltop Baldwin, Rosenthal and Silvergeiter in one 4-acre plantation. These bushes had done so well that the grower had planted another 3 acres last winter. The bushes were somewhat widely spaced by English standards, 12 × 6 ft, but this may not prove too wide under their growing conditions ; for example, the current season's shoots on Triple X were over 3 ft long and as thick as a man's thumb at their base. Picking began in mid-June and had been completed on all varieties when the farm was visited (5th July).

The Fruit Growing Institute at Verona is housed in a medium sized building of modern design erected in 1955. An experimental farm was established two years ago some way from the Institute. The Institute is supported by the Province from local taxes and by fruit growers ; it is not state-assisted. Dr. Bargioni, the director, is anxious to begin the selection of clonal rootstocks suitable for the Province.

Italian nurseries

The main nurseries visited were at Ferrara, at Bologna, and at Pistoia in Tuscany. Large-scale raising of black currant bushes, and of apples on M.IX, was being undertaken at Ferrara.

Cherry seedlings grow wild in the Apennine foothills, in Treviso, and on the hills of Udine ; Mahaleb seedlings come mainly from the Trieste area and Dalmatia ; Myrobalan from Bulgaria ; and peach seed from Yugoslavia. After stratification the seed is sown with sand and the seedlings later root-pruned in the ground by machine to sever the tap-root. Tree lifting machines can cope with 40,000 trees a day.

Pyrus betulaefolia is being used widely as a vigorous pear rootstock. It is reported to do well under dry soil conditions and has a wide range of compatibility including Williams'. At present stock trees are used for seed but the Ansaloni firm is making clonal selections of this species, propagating it by root cuttings. Much confusion has arisen in the past between this species and *P. calleryana* ; a useful point for identification is that the youngest leaves on *P. betulaefolia* are downy (like Jonathan apple) whereas those of *P. calleryana* are not.

Little success has been achieved with the double-shield budding method of double working. With Williams', buds of this variety are inserted into long shoots of the intermediate variety in August, these are cut into short scions for grafting on to rootstocks the following spring.

Both nurserymen visited in the Pistoia area had obtained good results from propagating Malling and Malling-Merton apple rootstocks by hardwood cuttings using the Malling ' quick dip ' hormone

treatment. They were also using the mist technique, under the supervision of Professor Breviglieri of Florence, and they were very satisfied with the results, but they too had experienced some difficulty with the hardening-off process. MM.109 had so far proved the best with this technique.

In the nursery attached to the Institute of Fruit Growing at Florence, Malling and Malling-Merton rootstocks were being grown in rows as low, clipped hedges, to produce wood for cuttings. A severe outbreak of woolly aphid had occurred and it was gratifying to see the attack confined to the Malling rootstocks, the Malling-Merton ones being entirely free. This may be of increasing importance to English nurserymen who may adopt this method of propagation in the future.

General

In northern Italy, as in England, there has taken place in recent years a gradual drift from the fields to the towns and their factories. In the Ferrara, Ravenna and Bologna districts this drift has been put as high as 30% since the last war. Wages paid to farm workers are very similar to those paid in England. In the Verona province, for example, an adult male worker receives about £6 a week, usually including a meal. On family holdings the hours worked are considerably in excess of those worked by ' paid ' labour. This applies to northern Italy—pay and conditions in the south and in Sicily may be very different. Many of the small growers appeared more or less self-supporting by way of intercrops and cattle feed often grown between the tree rows ; this probably makes them better able to withstand a poor fruit crop than a monoculture specialist.

In Italy, as in other parts of Europe, one is confronted with the growing importance of the replanting problem. This is specially important to the small grower who, unlike the larger grower, may be growing only one or perhaps two kinds of fruit. In Italy the replanting of peach land is a major problem since the life of an orchard is relatively short compared with other kinds of tree fruits.

The north Italian climate has many advantages for the fruit grower ; perhaps the chief ones lie in the moist and warm conditions of the early summer which doubtless account for the luxuriant growth characteristic of this region. In Ferrara the fruit receives a more favourable early start in the spring than does fruit north of the Alps. This is followed by a warm and dry July and August which helps to ripen both fruits and wood, while the soil, with a relatively high water-table, remains moist and cool under a dust mulch. Nevertheless, the climate has several disadvantages. The need for frost protection in the Adige Valley and elsewhere, and for irrigation in areas such as Verona, places additional capital charges upon growers. The heavy summer rainfall in the Adige Valley makes scab a major problem requiring three times the number of sprays usually applied in south-east England. Furthermore the climatic conditions that may be responsible for high fruit colour may also be responsible for the production of a tough skin on the apple which is not liked by all customers. Finally, the River Po is well known for its propensity to serious flooding, although expensive land drainage schemes are steadily reducing this risk.

By selecting heavy cropping varieties and adopting fairly close planting systems very heavy yields per acre are obtained. In the Adige Valley 23-year-old pear trees were still at 15 × 12 ft. Near Verona apples averaged 4-5 bushels a tree. Although 1,000 or more bushels to the acre can often be achieved, average yields for apples in the Ferrara area would be between 500 and 600 bushels an acre, and slightly less, 400-500 bushels, in the Adige Valley.

In conclusion, no one can leave the fruit growing districts of northern Italy without expressing admiration for the way in which the Italian has transformed the Plain of the River Po by his own efforts into what must be one of the most fertile and productive pieces of agricultural land in the world.

Acknowledgements

The provision of facilities for obtaining overseas experience of fruit growing conditions, as distinct from purely research visits to universities and research institutes, is the purpose of the East Malling Research Station Association's Fund for Overseas Orchard Experience. I wish to thank my Director, Dr. F. R. Tubbs, and the Executive Committee of the Research Station, as well as the numerous donors to the Travel Fund, for enabling me to undertake this tour.

I was received with kindness and hospitality by the Italian growers, and by university and advisory staffs who gave me freely of their time. I would especially like to record my gratitude to Professors Morettini, Breviglieri and Baldini ; to Dr. Bargioni of the Fruit Growing Institute, Verona ; and to Dr. Endrizzi of the I.C.E.

Mr. Akenhead, Mr. R. D. Webb and Mr. Basil Neame gave me much help and advice in planning my tour to the best advantage. Mrs. Rhind and Capt. Werth kindly acted as interpreters in the Alto-Adige and Verona areas respectively, as did Professor Toma at Ferrara. I am indebted to the Director, Meteorological Office, Harrow, for the climatological data for Ferrara and Bolzano. Finally, I wish to thank my wife for giving so much of her very limited free time to translation work.

ROOTSTOCKS FOR PLUMS

By ELIZABETH M. GLENN

The choice of plum varieties depends on local conditions, and on available markets for the fruit. Having selected the varieties, it is important to obtain them on the most suitable rootstocks, the choice of which will affect the size of tree and the amount of crop.

In the past, incompatibility between scion and rootstock limited the choice, but this is no longer so, as suitable vigorous and semi-dwarfing rootstocks for all plum varieties are now available.

Plum scion varieties and rootstocks cover not only a wide range of types, but more than one species. Thus if botanical relationships were important it would be very difficult to find a rootstock compatible with all varieties. However, relationship seems to matter very little ; for instance, Czar ' takes ' badly on Brussels (both showing characters mainly of *Prunus domestica*), but grows well on Myrobalan B (*P. cerasifera*).

It is important that the rootstocks should be clones of proved performance and true to name, as seedlings and mixed types usually show a wide range of vigour and varying degrees of compatibility. For example, Common Mussel clonal rootstock is compatible with all varieties of plum, but a mixture of Mussel types would vary widely, and some would fail to take the bud or would make trees which would die in the first few years.

Rootstocks in general use range from the vigorous Myrobalan B to the semi-dwarfing types such as Common Plum. Myrobalan B makes very large trees with most varieties—larger, in fact, than those same varieties would make on their own roots. Brompton is also a vigorous rootstock, but it makes trees a little smaller than on Myrobalan B, which do not crop quite so heavily. Common Mussel, Marianna, Pershore Yellow Egg, and Brussels all make medium-sized trees with most varieties. Common Mussel has been widely used in the past because it is compatible with all plums, but trees on it do not crop so heavily as on Marianna or Pershore Yellow Egg. Brussels is not recommended as it suckers much too freely in the orchard, and is incompatible with several commercial varieties. For smaller trees the semi-dwarfing rootstocks, Common Plum and St. Julien A, are available.

The vigour of the rootstock appears to have little effect on the age at which plum trees come into cropping. Trees on vigorous rootstocks may start to crop at the same age as trees on semi-dwarfing rootstocks. In one trial on this Station trees on Myrobalan B actually carried *more* fruit in the first seven years than those on more dwarfing stocks.

The effect of the rootstock on cropping appears to be largely an indirect one. The rootstock affects tree size, and the larger the tree the greater the crop—this applies both to young and to mature trees. However, the larger the trees the further apart they need to be planted. Where Victoria on Common Plum or St. Julien A needs to be planted 15 ft apart, on Myrobalan B the spacing would need to be at least 18 ft (Fig. 1). To give the same crops per acre, trees on Myrobalan B need to give 1½ times as much fruit as those on a semi-dwarfing rootstock. In fact, trees on Myrobalan B often crop even better than this, so that the crop per acre is heaviest with trees on this rootstock despite the wider spacing. This means that larger crops are obtained from fewer trees, with less capital expenditure on trees, planting, staking, etc.

However, vigorous rootstocks may make trees that are so large when mature that picking and spraying costs become uneconomic : this is especially true with certain varieties, for example, Cambridge Gage and Marjorie's Seedling. Also in some years vigorous rootstocks delay fruit ripening a few days. This may be a serious disadvantage with early varieties, for which the price obtained may drop rapidly within a few days of the first fruit reaching the market. These disadvantages should be set against the advantages mentioned above of increased crop per acre with less capital outlay.

With susceptible varieties many young trees are killed because their trunks are girdled by bacterial canker. Many of these deaths could be avoided if the trunks and crotches of the trees were of a resistant variety. Myrobalan B when ' run-up ' makes a stem which is resistant to canker, and it is recommended that susceptible varieties such as Victoria, Severn Cross, and Early Laxton should be high-worked on this rootstock.

A good rootstock for plums should (1) make the size of tree required, (2) induce heavy cropping, (3) be obtainable true to name and free from disease, (4) be compatible with all important commercial varieties, (5) have good anchorage, with little suckering in the orchard, (6) not delay ripening of the fruit, and (7) be easy to propagate and handle in the nursery.

A minimum of three rootstocks would be necessary to cover the first requirement, one for large, one for medium-sized, and one for small trees. Each of these should have the other six qualities listed above.

Unfortunately there is no plum rootstock which has every one of these good characters, but there are a few which are sufficiently near this ideal to be worth recommending.

For small trees, there are no truly dwarfing rootstocks for plums in general use, but there are some which are semi-dwarfing. The only important one in this class used to be Common Plum, but it is difficult to obtain it free from the bark-split virus, which particularly affects Cambridge Gage. Other disadvantages are that it suckers rather badly in the orchard, and is incompatible with certain scion varieties, including Czar, Marjorie's Seedling and damsons. Common Plum is now being largely

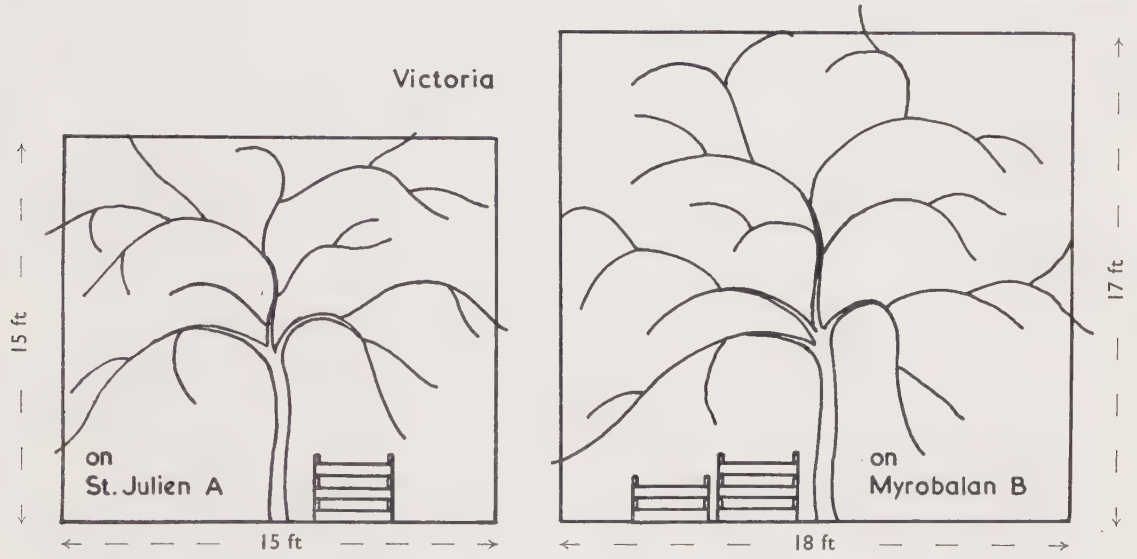

FIG. 1

Diagram showing tree sizes of 15-year-old trees of Victoria on St. Julien A and Myrobalan B, and mean annual crops 8 to 15 years. (1 tray = 20 lb)

replaced by St. Julien A, which is in the same vigour group and has several advantages. It is compatible with all varieties of plums, as well as with peaches, is available free from known viruses, and suckers less in the orchard.

Good rootstocks in the medium vigour group are Marianna and Pershore Yellow Egg. Marianna roots very easily from cuttings and hardly suckers at all in the orchard. Some varieties, such as Victoria, do very well on it, but it has a limited range of compatibility and is not recommended for Czar, Oullins Golden Gage, Marjorie's Seedling or damsons. Pershore Yellow Egg is shy to root in the layer bed, but modern methods with hardwood cuttings have given promising results, and this is likely to prove a better way of raising it. It is very popular in the West Midlands, and is compatible with all plums and damsons, but nurserymen's stocks are sometimes mixed and not true to name. A virus-tested selection will be available from this Station in a few years' time.

In the vigorous group are Brompton and Myrobalan B. From the nurseryman's point of view Brompton is an excellent rootstock. It can be propagated from hardwood cuttings, is clean and easy to handle in the nursery, and is compatible with all plums and damsons, as well as with peaches. But trees on it do not crop so heavily as on Myrobalan B. The latter is very easy to propagate from cuttings, but it is very spiny, so that the cuttings should be closely planted to reduce the growth of laterals. It is compatible with nearly all commercial varieties except Oullins Golden Gage.

This list of rootstocks can be further reduced to these three : Myrobalan B for large trees, Pershore Yellow Egg for medium-sized ones, and St. Julien A for smaller ones. These have a wide range of vigour, and would cover all varieties of plums, as well as damsons and peaches. Any variety that is particularly susceptible to bacterial canker could be high-worked on the resistant Myrobalan B.

Summary

The choice of rootstocks for plums is discussed and attention drawn to the merits of Myrobalan B, Pershore Yellow Egg, and St. Julien A.

CONTROLLING STRAWBERRY BOTRYTIS

By M. H. MOORE

Conditions favouring the fungus

The severe epidemic of fruit-rotting due to *Botrytis cinerea* in 1960 has emphasized that, given suitable weather, grey mould can quickly devastate a strawberry crop. The sort of weather that favours apple scab also favours this mould, but Botrytis completes its cycle from infection to fresh spore-production much more quickly, and is therefore even more menacing. Strawberries dry more slowly than trees after rain, mist, or dew because they grow near the soil where the humidity is higher and aeration less than at branch height. They are, moreover, a ready target for innumerable Botrytis spores released from dead or dying vegetation near by—including their own old leaves and also blossoms killed by frost. Straw holds moisture, which helps to establish the fungus, although straw is undoubtedly beneficial in keeping the fruits clean and reducing slug damage.

Sources of this very common fungus are legion and virtually impossible to eradicate, but strict attention to hygiene and good aeration can do much to help ; in fact, it is the first step to better control. Everything reasonable should be done to ensure that cropping plants dry as quickly as possible, but even so, the best-tended plantation is liable to attack. Redgauntlet is appreciably less liable than most commercial varieties.

Mode of attack

It is important in practice to appreciate that the bulk of the rotting often arises from infection starting at the green calyx or at the receptacle (plug) underneath, and not from individual rot lesions on the side of the ripe or ripening fruit, although some ripe fruits with side or tip lesions can, of course, be found in most plantations. The illustration (Fig. 1) shows that potential crop can be lost through calyx rotting at all stages from fruit-setting to the ripening berry, even on the same truss. Calyx infection spreads both ways; into the plug and shoulders of the fruit, and also back along the stalk. It may start from infected stamens or persisting petals, and control is then difficult because these parts of the flower are pressed between the calyx and the swelling fruit. Probably more frequently it results from infection at the junction of stalk and calyx, where spores are trapped in water held in a slight depression. Healthy berries can also be infected by contact with a rotting one in a cluster. Among green berries most losses arise from calyx infection ; such berries are not readily susceptible to direct spore-infection although they become more prone to it as they ripen. But whatever the origin of the infection may be, the powdery spores are eddied like small dust clouds from the ball of loose grey fungus surrounding a completely rotted berry, or they are splashed about in raindrops.

Picking-off infected fruits

Where infection has already started, rotting fruits should be regularly removed from the bed and destroyed, if possible before they produce spores. This routine prevents the development of the ' woolly ball '—a menace when it has to be removed during normal harvesting because to pick it releases innumerable spores into the air just above the plants and on to the picker's fingers.

Control by spraying

Research in this country, on the Continent, and in the U.S.A. has established the merits of thiram and captan as the most effective chemical sprays available against this disease. Moreover, research workers agree that, to guard against possible attack at any time from flowering to harvest, a sequence of three or four thorough spray-applications is necessary, *starting in full blossom or at early petal-fall.* Low-volume spraying is satisfactory provided that it gives good cover of the trusses and that the quantity of *active* chemical is not reduced below high-volume rates, 3-4 lb per acre per application. Dusting, however, is less satisfactory, especially when infection has already begun.

This spray schedule should give even better control in commercial practice than in experiments, where the unsprayed plots act as advance bases from which the fungus can repeatedly attack. It has been recommended for several years, and therefore it is the more surprising that an epidemic like that of 1960 should have arisen. A main difficulty clearly stems, however, from the acute nature of the disease; in some seasons it suddenly flares up, and in others it gives no trouble. To persist steadily with an annual routine spray-programme is tedious and costly under such conditions. Another difficulty lies

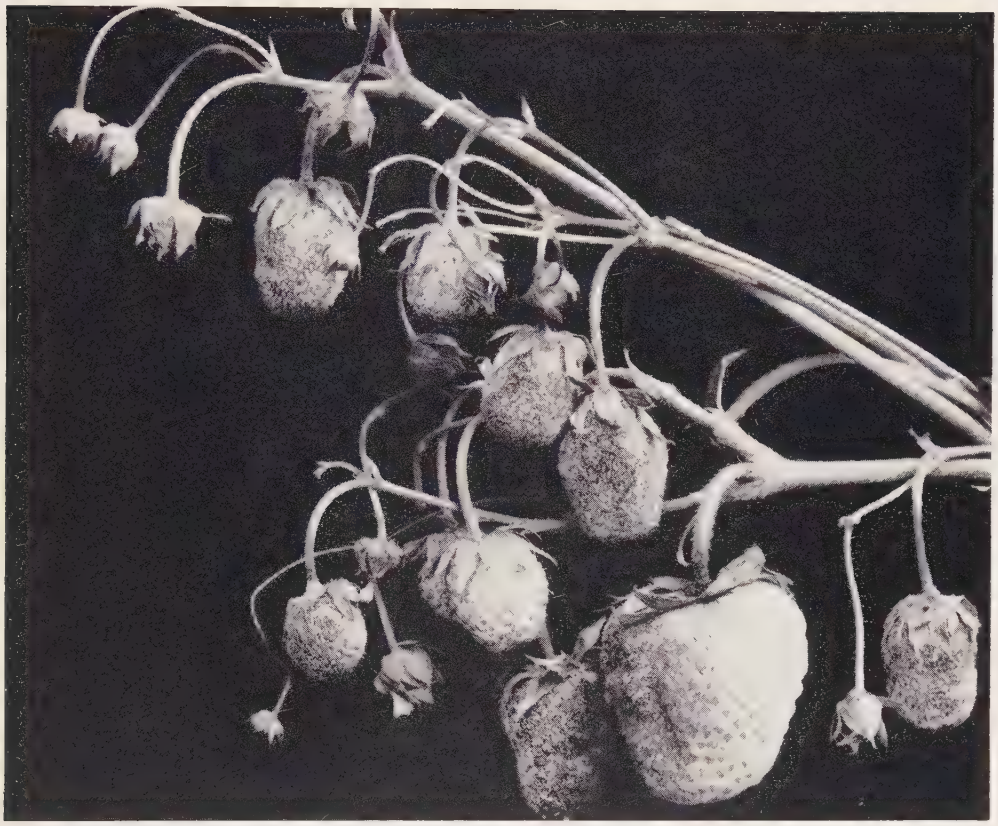

Fig. 1

Truss of half-grown Royal Sovereign strawberries ruined by Botrytis rot. Note that infection started at the calyx end of the berries, sometimes in the stalk, and that some small fruitlets were rotted just after setting. Regular spraying from blossom-time, or alternatively, a spray in bloom followed by a stronger spray directed down on to the trusses a few days before the stage illustrated, would probably have saved most of the crop

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in the risk of residues on fruits sprayed just before harvest, and the added possibility of off-flavour if these fruits are canned. Moreover, spraying near harvest on a large scale is hazardous because the tractor wheels are likely to cause serious damage to the crop. Slightly wider spacing of the rows may facilitate tractor spraying among the vigorous plants now grown, and it would be no disadvantage in some other respects, such as aeration.

A suggestion for which there is practical though as yet little experimental evidence is based on the observations noted under ' Mode of attack ', and it might dispose of most of the difficulties. As an alternative to adopting a regular spraying routine, some growers may prefer to spray only when conditions in the strawberry bed clearly threaten a Botrytis attack; either at the onset of 'Botrytis weather', which every strawberry grower can now recognize by experience, or when the first infection is seen under conditions favourable for the attack to extend. *The first and one of the most dangerous occasions to be countered is at main flowering time*, for when the petals and stamens become infected there is likely to be danger later, at fruit-swelling, especially if Botrytis weather comes again. At flowering time, if the conditions make spraying desirable, thiram or captan should be used at normal recommended rates. Later, when the arrival of similar conditions warrants spraying again, a second, much stronger, application should be made, and it may suffice till harvest. The aim should be to spray vertically down on to the trusses before the weight of the fruit flattens them to the straw. Thus a layer of fairly strong fungicide would protect the calyx, especially the depression near the stalk, and little of it would fall on the fruits hanging under the calyx umbrella (Fig. 1).

Evidence from glasshouse experiments showed that 0·5% of active material as a wet spray would protect ripening berries from most Botrytis infections, even under artificial conditions designed to promote as much infection as possible. This quantity of active material would be provided by $6\frac{1}{4}$ lb per 100 gallons of an 80% wettable powder or 10 lb per 100 gallons of a 50% wettable powder. These sprays are about 3 times normal strength, but as a single spray at this rate might render further applications superfluous, the weight of chemical required in a season would be similar to that necessary for three post-blossom sprays of normal strength.

If, as sometimes happens, conditions favouring Botrytis do not arise until picking is almost due to begin, spraying poses a difficult problem. In the absence of an earlier spraying the fruits are entirely unprotected, and presumably must remain so if to spray would contravene a processing or other contract. In other circumstances, spraying is the only sure way to save the crop, and a normal concentration of chemical should be used.

Faced with the possibility of this dilemma at harvest time, however, some growers may well think that a single stronger spray applied vertically downwards when most fruits are about half-grown is worth carrying out as an annual routine, whatever the weather at the time. In warm, dry summers this spray may seem to have been unnecessary, although the effect of persisting dews must not be lightly discounted, but when applied before the onset of a wet strawberry harvest it could pay good dividends.

Summary

1. Botrytis rot (grey mould) can ruin a strawberry crop during wet weather at any time between blossoming and harvest.

2. In some seasons the disease may run riot on the petals and other floral parts, and on frosted blooms, and a first spray of thiram or captan at normal strength during blossoming is therefore recommended to prevent serious trouble later.

3. Two or three more sprays are necessary to give good control, and especially to safeguard the valuable first picks.

4. As an alternative to routine post-blossom spraying (No. 3), the bloom spray (No. 2) could be followed by one spray of thiram or captan at 3 times normal strength. It should be directed down on to the trusses to protect the calyces when most berries are about half-grown (see illustration), or earlier if a Botrytis attack is imminent.

PROGRESS IN RESEARCH ON FRUIT CROPS IN 1960

By B. F. SELF

Some aspects of special interest in the reports of the Research Sections are presented in this article for the information of fruit growers.

Rootstocks and interstocks

Malling-Merton rootstocks

The Malling-Merton rootstock demonstration plots were visited during 1960 (p. 7). These 33 plantations are sited on a range of soil types and conditions in all the important fruit-growing areas of England. The trees on most of the plots are now between seven and nine years old and it is, therefore, too early yet to draw definite conclusions. They are, however, behaving very similarly to the trees on these rootstocks at East Malling when they were at the same age. Rootstocks that have done well under a wide range of soil conditions include MM.106, MM.111 and M.XXV. The majority of these trials are now at a useful age and should be of interest to growers in the neighbourhood of the plots.

Rootstocks for pears

There is a very limited range of rootstocks for pears available in this country. Many growers would like a stock of greater vigour than Quince A that would be particularly suitable for light soils. The more dwarfing selection, Quince C, is little used now, because the existing commercial stocks are infected with virus. A replacement for this stock is desirable.

Nursery trials with a number of quinces obtained from Provence and Angers have indicated that some are more vigorous than Quince A. In a small-scale rootstock trial, now nearly 20 years old, certain selections from a range of quinces that were obtained from the Caucasus have produced trees less vigorous than Quince A, some being even more dwarfing than Quince C. The best of all these potential rootstocks for pears have been selected and are being compared with Quince A in a field trial planted in 1960 (p. 7). The scion varieties are Conference and Beurré Hardy.

Clonal pear rootstocks are usually difficult to propagate. Some ready-rooting clones have been selected from the progeny of seed collected in Turkey and they appear to be compatible with the variety Williams' Bon Chrétien, which often shows incompatibilities with quince.

Propagation tests have eliminated all but six of the original 100 seedlings of the Chinese pear, *Pyrus calleryana*.

Interstocks

Interstocks, or intermediate stem pieces between the rootstocks and the scion, have been used to a moderate extent in the U.S.A. In one system used in America, selected seedling stocks are grafted with 5-in. stem pieces of a dwarfing Malling stock, which is subsequently budded with the scion variety. The object of this operation is to combine a desirable dwarfing habit with good anchorage and thus dispense with the costly operation of staking small trees. How much effect does an interstock have on the growth and cropping of a variety? Does this influence vary with type of interstock, for example M.IX, M.VII, etc.? Is the effect proportional to the length of intermediate stem piece? A trial has been planted to obtain information on these questions (p. 7). Seven rootstocks with a vigour range extending from M.IX to Crab C have been used as either 2-in. or 14-in. intermediates between the rootstock M.II and the variety Cox's Orange Pippin.

A set of trees is being prepared for a second trial, using 5-in. dwarfing interstocks on MM.104.

Height of budding

If rootstocks are budded higher than usual and planted deeper than usual, is the anchorage considerably improved? Is it necessary for such trees to be staked after planting? An experiment has been started to study this problem (p. 8). Trees of Cox's Orange Pippin on M.VII, budded at 6 in. and 12 in. above soil level, have been planted out with their unions all at 6 in. above soil level. The trees are not supported and observations on their anchorage will subsequently be made.

Collar rot of apples, caused by a soil-borne fungus, is a serious disease in some areas. The variety Cox's Orange Pippin is very susceptible but, fortunately, most of the commonly used rootstocks show good resistance to the disease. If such stocks are budded high there is less risk of the variety becoming

infected. Two nursery trials show that budding at 12 in. above ground level is practicable and very satisfactory maiden trees have been produced. A paper on this subject appears on page 49.

Propagation

Winter stored hardwood cuttings of rootstocks are usually budded in the year following the season of planting. Preliminary results from a new trial with long cuttings of the plum rootstocks Myrobalan B and Brompton indicate that they can be successfully budded in the same year as planting (p. 8).

It was reported in 1959 that softwood cuttings of rootstocks rooted easily under mist but that difficulties had been experienced with the establishment of the rooted shoots. In a recent experiment, long cuttings (16 in.) have been rooted under mist and successfully transferred to the field under sprinkler irrigation (p. 8).

Pruning

There is a considerable difference between the time taken to prune trees by light systems of pruning than by more severe methods. Investigations have been started to see whether a further reduction in pruning time is practicable without adversely affecting fruit yield and quality (p. 9). The new experiment has been superimposed on an existing pruning trial of trees of Cox's Orange Pippin and Laxton's Superb and compares pruning every year with pruning only once in two years.

Breeding

It would be very desirable to have commercial apple varieties naturally resistant to scab and mildew. A long-term programme has started at East Malling to breed disease resistant varieties making use of the results of work already done in the U.S.A. on the inheritance of scab resistance in apple (p. 9). It is hoped, eventually, to transfer characters conveying resistance into some new apple varieties being raised at the Station. Possible sources of resistance to apple mildew are also being investigated.

Weedkillers

Successful weed control, without adverse effects on fruit plants, is again reported with simazine (p. 9). One material, monuron, has, however, caused injury to black currants when used at 5 lb per acre, resulting in a reduction in growth and yield. This herbicide, applied at 10 lb per acre, caused severe injury to both black currants and raspberries. In a trial with monuron on tree fruits, weed control has been good but a pear tree has shown signs of injury.

Soft fruit trials

Because of low yields and poor fruit quality there has been little commercial interest in loganberries until recently. The health and cropping of selections of loganberry from various countries are being tested at East Malling. In a new trial of virus-tested plants the yields averaged about 12 lb per plant, which is equivalent to about 4 tons per acre (p. 10). This is a very heavy crop for loganberries in their first cropping year. The clone LY59, which was released with the co-operation of the Long Ashton Research Station to the Nuclear Stock Association for multiplication, is included in this trial. It is now available to growers through the Ministry of Agriculture's Certification Scheme.

A thornless sport of the blackberry Bedford Giant is being compared with a normal thorned selection of this variety. Both types yielded about 30 lb of fruit per plant in their first cropping season.

Frost damage

Spring frosts damaged black currants and reduced their crops in 1960, but Amos Black suffered less than a number of other varieties (p. 11). Some growers tie bushes up with a loop of string in the winter to make cultivations easier and in the hope of reducing frost damage. Several bushes treated experimentally in this way suffered less frost damage. The ties, however, should be released before the leaves have grown much or the new growth and fruit development is abnormal.

Continuous water sprinkling, at the rate of about $\frac{1}{10}$ in. per hour, has given successful protection from spring frost damage on apples in recent years and this technique is now being applied to black currants. Preliminary experiments suggest that more water must be applied to obtain similar protection.

Irrigation

The inter-relationship between the effects of soil moisture and soil nitrogen is being studied on trees of Laxton's Fortune growing on a light sandy soil. Supplementary water and high nitrogen each gave a very similar influence on yield in 1960, the increase being about 60% compared with the unwatered trees receiving low nitrogen (p. 20). Where the irrigated and high nitrogen treatments were combined the crop was increased by 95%, but with an adverse effect on fruit size.

The effects of the dry summer of 1959 were apparent in the growth and cropping of unwatered trees on light soils in the following year. Thus the irrigated trees of Laxton's Superb yielded 50% greater crops than the unwatered ones, in spite of the wet season in 1960. Shoot growth also was limited on the unwatered trees.

The total yield differences between irrigated and unwatered raspberries were much smaller than in 1959. Less water was, however, needed but the response to irrigation, in terms of increase of crop in relation to the amount of water given, was as great as in previous years. Raspberries growing in a straw mulch cropped as well as irrigated plants.

The drought of 1959 seriously affected the growth of black currants with the result that a relatively poor crop was picked from the unwatered plots.

Nitrogen

In the manurial trial on trees of Cox's Orange Pippin, which is now 30 years old, there was a noticeable response in yield to nitrogen fertilizer on both the sward and the cultivated plots (p. 21). The foliage on trees in the grass plots receiving nitrogen was considerably darker than the foliage without nitrogen. Seasonal trends in the amount of nitrogen in the soil are being investigated on various plots of this trial. As might be expected, the soil nitrate levels were much lower in grass than in cultivation. The amounts of nitrate in the top two feet of soil in plots that received 'Nitro-chalk' in February and April reached their highest level by June and then fell as the wet weather developed. In 1959, however, the high soil nitrate levels were maintained until October.

Magnesium

Striking results from the use of Epsom salt sprays to overcome magnesium deficiency were reported in 1959. This year pre-blossom sprays of Epsom salt used on dwarf pyramid trees of Edward VII on M.VII prevented leaf scorch on spur leaves but did not reduce the deficiency symptoms on extension shoots (p. 21). The relative efficiency of foliar sprays of magnesium chloride and magnesium sulphate (Epsom salt) has been compared. Five post-blossom sprays of 0·83% magnesium chloride, which contains the same concentration of magnesium as 1% Epsom salt, were as effective in reducing leaf symptoms as five sprays of 2% Epsom salt.

Most of the trials with Epsom salt sprays have either been on dwarf pyramid apple trees or with apple rootstock stoolbeds. Now similar spray treatments are being applied to three varieties grown as bush trees on M.VII and M.II. Magnesium deficiency symptoms have been observed on many of the leaves of the trees on M.VII but only on comparatively few leaves of those on M.II. It will be interesting to compare their response to magnesium sprays.

A previous experiment on apple stoolbeds has shown that fewer shoots were attacked by apple mildew where repeated sprays of Epsom salt were applied, compared with untreated stocks. A study is being made with potted rootstock layers to find out what effect these foliar sprays have against apple mildew (p. 22). Some reduction in disease incidence was obtained by merely spraying with a wetting agent. Greater control was achieved with Epsom salt in addition to the wetter. Since the best protection was achieved by a single application one day before the shoots were inoculated with mildew spores, it seems that the spray deposit was the main factor preventing infection. No direct relation has yet been shown to exist between the magnesium content of shoots and the degree of infection by mildew.

Soil survey of pH

Most fruit plants grow best in soils that are just slightly acid. The soil reaction influences the availability of nutrients. Thus some mineral deficiencies as well as certain toxicities are associated with particularly acid soils. Similarly, deficiencies of other elements occur on very calcareous land.

A most detailed pH survey has been completed on the soils of the Research Station and Trust Land (p. 77). Altogether 9,204 samples were taken and subsequently tested in the laboratory. The surface soil was found to be more acid than the deeper soil. Most of the land has a pH near, or just below, neutrality. The very acid areas were found, as expected, on the light soils on the Folkestone

Beds. The low pH on such land is partly due to natural leaching but also to the continued use of acidifying fertilizers such as sulphate of ammonia. A small area was very alkaline. On this land the soil has a high content of lime which is due either to lime carried in spring water or to the underlying calcareous ragstone on shallow soils. The results of this survey will be of great help in siting and planning future field trials as well as in the more efficient use of fertilizers on existing experimental plots.

Orchard pests

Codling moth

Both the biology and chemical control of the codling moth are being examined so that improved methods of control can be found. A report of the research in progress on this pest formed part of a Members' Day in November.

Studies in other countries have suggested that the codling moth lays most of its eggs at dusk. In England the habits may be slightly different. In 1960, codling moths in a cage placed under apple trees laid as many eggs in the day as at night.

The adult moths are usually in flight from early June until early September. The time they first appear varies from year to year ; in some seasons they emerge as early as mid-May and in other years as late as mid-June. A high proportion of the larvae that hatch early in the season attack the fruit at the calyx end. A petal-fall spray of lead arsenate, applied with a wetter, results in a considerable reduction of injury caused by first generation larvae, particularly at the calyx end of the fruit. The harvest residues of insecticide are not appreciably increased by the addition of the petal-fall codling spray.

Other chemicals are also being used for the control of this pest. DDT and an organophosphorus insecticide have been used at three different times in 1960. Both materials were most effective when used in mid-June, when the larvae were hatching, and in early July.

Apple aphids

The apple-grass aphid migrates in May from the apple tree to its summer host, usually the annual meadow grass. Later it returns to apple to lay its eggs. Following dry summers, which do not favour the growth of the grass, the aphid populations are usually low. An examination of the number of aphids found on trees in the early autumn can be used to forecast the level of infestation in the coming spring (p. 31).

Mites

A modified spray programme has been used in one orchard to investigate the interaction of fruit tree red spider mite and its main predator, the black-kneed capsid (p. 31). The natural balance was disturbed in 1957 when the capsid was killed by a DDT spray in August. Although the mite population was high in 1958 it was somewhat reduced by predators in the following year. In 1960 red spider was again under natural control. Thus it took two years for this beneficial insect to build up.

Three species of Bryobia mite are associated with fruit crops, but they have not yet been given common names (p. 31). One species, which has three generations on apple and pear, is becoming common in Kent orchards, particularly in East Kent. Another Bryobia mite lives mainly on grasses and herbaceous plants but will feed on apple and pear in the spring months. This species breeds throughout the year. A third species is confined to the gooseberry. So far only the biology of these mites has been studied but in areas where *Bryobia* is a problem, growers are obtaining promising control with some of the chemicals used against fruit tree red spider mite.

Eelworms

In 1959 it was reported that a dagger nematode, a species of *Xiphenema*, was able to transmit the soil-borne virus disease, arabis mosaic. In glasshouse tests, dagger nematodes were still able to infect petunia seedlings with arabis mosaic virus after a period of 30 days without access to infected plants (p. 33). The results of field surveys show that this eelworm usually exists in very small numbers in cultivated or grassland fields although moderate numbers have been found in hedgerows. Populations may reach quite high levels, however, under suitable host plants such as the strawberry. The relationship between the distribution of this nematode to that of soil-borne viruses is being examined.

In experiments under sterile conditions the amount of injury caused by attacks of the root lesion eelworm has been shown to be influenced by certain chemical compounds in the apple tree roots (p. 33). The same eelworm can attack strawberry plants. On a field heavily infected with root

lesion eelworms, strawberry plants grew better on plots which had been fumigated with a nematicide than on untreated land.

Spray damage

Bordeaux mixture sprays, which are applied to cherry trees in mid-August and mid-September against the summer phase of bacterial canker, can cause leaf injury. Usually six pints of cotton seed oil are added to each 100 gallons of spray to prevent defoliation but the oil is fairly expensive. It was hoped to improve the efficiency of the oil by adding an emulsifying agent. In 1960 an attempt to reduce the amount of oil to 3 pints failed to prevent leaf damage, although a good emulsifying agent was included (p. 37).

Amongst several materials that have been compared for the control of black currant gall mite, fluoracetamide was found to cause leaf injury and reduce the crop on the varieties Baldwin and Wellington XXX (p. 37).

Some chemicals used as sprays on certain varieties have only a small margin of safety. Two different chemicals used together often lead to increased injury but occasionally can cause less injury to the plant than the single material applied individually. Trees of Lane's Prince Albert on M.VII were sprayed with dinocap (Karathane) or captan or a combination of both (p. 113). The dinocap programme caused a reduction in fruit set and subsequent crop compared with the captan only programme. Where the dinocap and the captan were applied together there was only a slight adverse effect on fruit set. When dinocap is used it is much safer to apply captan at the same time, even at a lower rate than that recommended for scab control.

In a fungicide trial against pear scab, Doyenné du Comice fruits were severely russeted by colloidal sulphur applied as a concentrate. This variety seems unable to tolerate any form of sulphur.

FUNGAL AND BACTERIAL DISEASES

Apple scab

There was virtually no late season scab infection in 1959 and no ascospores were caught in a Hirst spore trap in a Bramley orchard after mid-May (p. 25). Although the weather conditions favoured the liberation of spores there were fewer ascospores collected than in the previous two years.

In a laboratory experiment using several chemicals at different concentrations, only 0·1% phenyl mercury chloride (about 40 times the strength of a commercial PMC spray), applied in the autumn, completely prevented the production of scab ascospores on infected overwintering leaves.

More scab infections were obtained in glasshouse experiments when the environmental conditions fluctuated than when they were uniform. High humidity accompanied by a falling temperature favoured infection. An interruption of the wet conditions by a dry period of several hours did not prevent infection.

Six curative sprays applied immediately after infection periods were compared with seven protective sprays, and both programmes gave almost complete scab control last season. The unsprayed trees were heavily infected.

Gloeosporium diseases

The disease cycle of the fungi causing cankers on apple wood and lenticel rot on apple fruit is being studied. Small tubes have been used as spore traps to catch rain water from the surface of apple branches. The traps are collected after rain and the spores in the water examined. The spores of one *Gloeosporium* fungus were found to become more numerous during the autumn, especially in November, and to become less plentiful during the winter (p. 26). When stubs on spurs and branches were collected from the orchard and brought in to the laboratory a similar seasonal pattern of spore production was obtained.

Verticillium wilt

Strawberry varieties differ in their resistance to the soil-borne disease Verticillium wilt. Under certain conditions the plant can tolerate the fungus without showing symptoms. In a trial on a wilt infected field, Cambridge Vigour was most susceptible to the disease, 80% of the plants becoming infected (pp. 28, 94). Up to 38% of the plants of Huxley were infected, 36% of Cambridge Rearguard, but less than 3% of Cambridge Favourite, Royal Sovereign, Merton Princess and Talisman.

There are two species of the wilt fungus that can attack strawberry. The species that attacks hops, *Verticillium albo-atrum*, is very uncommon on strawberries but is more severe in its attack than

V. dahliae, which occurs on potatoes and other plants. Talisman is the only strawberry variety which is relatively tolerant to both species, but this tolerance would probably break down if this variety were to be grown repeatedly on wilt infected land.

Bacterial canker

Potential cherry and plum rootstocks are being tested for their resistance to bacterial canker. About 1,200 mazzard cherry seedlings and 67 clones from seedlings of St. Julien of Orleans plum have been inoculated with bacteria (p. 24). In each case about two-thirds of the plants have been found to be very susceptible to the disease.

Bordeaux mixture and some other sprays are known to kill many of the bacteria on the leaf surface of cherries. Are these surviving bacteria more virulent than on unsprayed trees ? An experiment has been in progress to answer this question. There is no evidence to show that virulence is related to the previous spray treatment.

In a new trial against bacterial canker on cherries different spray strengths and times of application have been used. The superiority of Boreaux mixture as a bactericide was again demonstrated. The spring sprays greatly reduced the numbers of bacteria on the leaves, but the population subsequently increased and was eventually about 10% of the number on unsprayed trees.

VIRUS DISEASES

Tree fruit viruses

The soil-borne virus, raspberry ring spot, is associated with rasp leaf on cherry trees in Kent and Berkshire (p. 29).

A virus disease of Noble cherry trees causes the leaves to turn yellow and fall early. The buds sometimes die and gum so that the symptoms can easily be confused with those of bacterial canker. This disease has been proved to be similar to a necrotic rusty mottle found in North America.

Five more varieties were added to the list of virus-tested trees available for distribution to Members in 1960. The new Mother trees were the pear Doyenné du Comice M.204, the cherry Merton Reward M.520, and the plums Yellow Egg (Pershore) M.305, Czar M.311 and Prune Damson M.313.

Such trees are distributed to the industry to provide a clean source for propagation.

Soft fruit viruses

All the 15 strawberry varieties tested for their resistance to the soil-borne virus, arabis mosaic, were, unfortunately, found to be susceptible to this disease (p. 29).

A special investigation of the virus diseases of black currants is now in progress. In a trial planted in 1954 black currant yellows (see 1951 Annual Report) reduced the crop of both Baldwin and Wellington XXX by about 70% during a three-year period. The virus stunted the bushes and reduced both the number and size of fruits.

Fruit storage

Many factors influence the size of apple fruits, including pruning, fruitlet thinning, irrigation, and manuring. Young trees and trees bearing light crops generally produce large fruit. Large fruits do not usually store well but develop more low temperature breakdown and bitter pit than smaller fruits. It is, therefore, wise to market the very large fruit first and store only the medium sized samples. Both the number and size of cells within the flesh of an apple fruit affect its size. A paper on this relationship appears on page 120.

Following the very dry summer of 1959 fruit was stored from trees of Cox's Orange Pippin in an irrigation trial at the N.A.A.S. Experimental Horticulture Station at Luddington. Although at times the unwatered trees showed drought symptoms there was more low temperature breakdown and bitter pit in the samples taken from trees in the irrigated treatments than from those in the unwatered plots (p. 38).

Some of the treatments trees receive in the orchard have been shown to be consistently related to the subsequent behaviour of the crop in storage. What sort of changes are taking place within the fruit to have these effects upon storage life ? What changes do soil management and manurial treatments produce in the fruit ? The Biochemistry Section is investigating these questions in developing and mature fruit from differently manured trees (p. 18). A particular study is being made of the changes in concentrations of various organic acids, some of which are involved in the respiration of the apple after picking.

Weather records

Records are taken daily of rainfall, temperature, sunshine, and wind. East Malling is one of the many Weather Stations in the country which regularly forward data to the Meteorological Office. Such information is not only of general interest but of direct value to research.

A full report of the weather conditions experienced at East Malling during 1960 can be read on page 61. The total rainfall was about 36 in., which is over 9 in. above the average. It was the wettest year since 1927. The amount of rain in the early summer was only moderate and the soil moisture deficit in July reached 4 in. The rainfall in the second half of the year, however, was equal to the average for a complete year. Despite such a wet season the figures for sunshine were not as low as in 1958.

Summary

Items of particular interest in the reports of the Research Sections for 1960 are summarized for fruit growers.

PROGRESS IN RESEARCH ON VERTICILLIUM WILT AND VIRUS DISEASES OF HOPS IN 1960

By R. V. HARRIS

This is the annual review for 1960 of items of special interest to hop growers in the general Research Report of the Plant Pathology Section (see p. 24).

PROGRESSIVE VERTICILLIUM WILT

The authentication this year of further outbreaks of progressive wilt in the West Midlands has intensified the urgency of our work with the Department of Hop Research at Wye College on producing a substitute range of new highly wilt-tolerant varieties. It has also increased the need for improved methods for countering the spread of its cause, the so-called 'virulent strain'* of the fungus *Verticillium albo-atrum*, in hop soils. It would be most premature to assume that the present campaign to restrict progressive wilt, and therefore the use of tolerant varieties, to an area in the south east is now doomed to failure. But it would obviously be as foolish not to be prepared, if it does fail, for the replacement of *all* the sensitive varieties *everywhere* by equivalent wilt-tolerant ones. Clearly the brewer can no longer afford to assume that adequate supplies of Fuggle and the other staple varieties are certain to be available to him indefinitely; he should start trying wilt-tolerant substitutes. And for the same reason our research programme is planned to strike a balance to cover *both* eventualities and, at the same time, to keep a watch on the virulent fungus itself for yet further changes of its wilting powers in an unfavourable direction.

Trials of new tolerant varieties and seedlings

Our recently released Density, Defender and Janus have entered on the final stages of their trials, i.e. their commercial trials by the growing and brewing industries

In our review for 1957 was noted the Station's decision to release these varieties for commercial propagation in the winters of 1956 and 1957 on the grounds of the conspicuously favourable results of their initial cultural and brewing trials over the previous 7 years. With the 1959 crop of these varieties the large-scale commercial growing and brewing phase of their trials had therefore fairly started, the phase which will finally decide their commercial acceptability, or otherwise.

Although the relatively small 1959 harvest of each consigned to The Hops Marketing Board received valuations 'on merit' comparing favourably with those of the current Fuggle crop, no less than 66% of the crop of Density, 100% of Defender and 12% of Janus remained unsold. This truly discouraging *debut* was commented on, somewhat ironically, in a circular letter subsequently issued by the Board, to the effect that Density and Defender 'are not wanted by brewers when hops of the normal commercial varieties are available'. The effect of these conflicting circumstances, and of this *caveat* on the still very limited growths of these varieties, in the culturally unfavourable 1960 season, combined with the low per cent acceptance quota fixed by the Board, was truly disastrous, virtually no clean and representative samples of Density and Defender being available just when the brewers were being advised to begin to try substituting them in the grist.† With Janus, however, the situation was alleviated by the interest in it shown by a well-known firm of brewer-growers who kindly made well-grown samples of it available. It is to be hoped that this threat of premature decease without proper commercial trial to two at least of these new wilt-tolerant substitute varieties can be countered in 1961 by ensuring the production of typical, well managed and harvested samples. In this connexion it should be borne in mind that no further new tolerant varieties can be expected for commercial trial before 1965-66 (see below).

Three Wye-East Malling candidate seedlings completed the first season of their farm trials

This year saw the first hill to hill recording of wilt tolerance on the new farm trials of the three short-listed candidate seedlings mentioned in last year's Review. As earlier intensive testing has shown each to have a degree of wilt tolerance higher than that of Keyworth's Midseason, their prospects

* Thus distinguishing it from the 'mild strain' responsible for fluctuating outbreaks in Fuggle and the other sensitive hops.

† See F. N. Richardson, 'The Future of the Fuggle', The Brewing Trade Review, October 1960.

under normal commercial growing are promising. But should one or more of these new seedlings 'make the grade' on the results of these farm trials and of brewing trials on their 1962 and 1963 growths, the earliest at which any stocks of such varieties could be available to wilt affected growers generally would be about 1966. This deserves particular attention in view of the present situation with Density, Defender and Janus. For further particulars of the trials of these seedlings see the Annual Report for 1959 of the Department of Hop Research at Wye College, page 15.

Research on wilt tolerance

Farms where severe wilting of tolerant varieties has occurred continued to be closely watched and studied and the search for others continues

Here we have in mind the disturbing possibility that further changes for the worse in the wilting powers of the virulent fungus may have occurred, or, more hopefully, that these farms may merely represent instances of wilt being encouraged by favourable soil conditions.

Last year we were pleased to be able to report that the level of wilt on all the farms thus under observation had drastically fallen to the reasonable figure of around 6%. In wet 1960, however, as might have been expected, it was again higher than in 1959 but did not return to the very high levels recorded in 1958.

To discover whether such cases are on the increase a further questionnaire was circulated, this time to a total of 43 growers of the tolerant varieties. Since this has so far produced no additions to our present list, the general situation remains reassuring.

A laboratory and greenhouse experiment was made to find whether the wilting power of the virulent fungus is changing

It is well known to the scientist that laboratory cultures of the virulent fungus derived from single spores from a parent culture commonly differ in appearance, for instance in the amount of dark-coloured growth produced, some being completely white. So far, however, there has been no indication that, say, a white culture from such a series is necessarily a more or less powerful wilt producer.

This year the wilting capacities of eight such cultures from a parent culture of the original virulent fungus and differing between themselves in appearance, were compared with each other and with that of the parent culture. The result was that all, including some white forms, proved highly virulent although some caused more rapid wilting than others. This experiment thus gave no support to the view that strains of different virulence may be arising.

Research on the direct control of progressive wilt by measures aimed at the destruction of the virulent fungus

The harvesting by stationary machines of infected gardens of sensitive and tolerant varieties can be a major cause of spreading progressive wilt

Because of the resistance mechanisms which operate in differing degrees in both sensitive and tolerant varieties, symptom-free hills of both may contain the virulent fungus. The resulting risks of spreading the disease in machine-harvested gardens of both types of varieties were assessed experimentally this year. The results of these experiments were very disturbing.

Thus in a garden of Whitbread's Golding Variety tested in 1959, of the 1,525 hills examined the day before machine harvesting, the cut bine of 17·5% was found to be infected. Of these only 4·8% were showing wilt symptoms at that time and no less than 12·7% were symptomless. Then, the following day, these bines were followed to the machine and the waste from them was collected. When this was tested in 1960 on the sensitive Fuggle, it proved to be highly infective, up to 100% of the plants being killed in some tests.

It is, therefore, very evident that however minutely a wilt garden is inspected and 'rogued' beforehand for hills and bines showing symptoms, the risks of spreading the disease by harvesting remain high. Full details of these important results, with discussion of their practical implications, especially with regard to the risks from the composting and return of infective waste, are presented in a paper to be found elsewhere in this report (p. 100). See also below.

Joint work with Wye College and the N.A.A.S. on the possibility of rendering machine waste from infected gardens inocuous by composting confirms that the fungus is very resistant to high temperatures

In last year's review we stressed the fact that experiments on the destruction of the virulent fungus in bine by heat had shown that it was highly resistant to such treatment. This year these experiments showed that continuous exposure of such bine for 7 days at 104° F or for 15 minutes at 140° F

was necessary to render such bine harmless. On these results an experiment was started this year on the effects of composting on the already proved infectivity of machine waste. Pending the results of this work, growers are advised in the paper mentioned above that ' in the present stage of our knowledge, burning is the only safe method of disposing of infected hop waste, difficult and wasteful as this may be '.

Continued experiments have further confirmed the contrasting effects of weeds and weed-free grass cover on the survival of the progressive fungus in hop soils

A field experiment, now in its fourth season, has confirmed once again that the survival of the virulent fungus in the soil is encouraged by weeds. This experiment, referred to in the review for 1958, compares effects of various cropping and soil management programmes on the survival of the fungus. Here, after an initial fall in the soil population of the fungus in the second and third years under a weed tumbledown, a marked increase occurred in the amount of fungus recovered this year.

In contrast to this result under weeds, no fungus was recovered this year from the plots of this experiment under a weed-free grass cover, as compared with positive but decreasing amounts recovered in the three previous seasons. The prospect of being able to speed up considerably the reduction of the virulent fungus in hop soils by applying appropriate cropping and soil management programmes is thus very good.

VIRUS DISEASES

Nettlehead virus was mechanically transmitted from hop to hop in greenhouse experiments

By ' mechanically transmitted ' is meant that Early Prolific hop plants were successfully infected with nettlehead by rubbing their leaves with sap extracted from infected plants of the same variety. It was not, however, just rubbing and just sap ; that would most probably not have been successful. But the extracted sap had been mixed with a chemical designed to discourage the normally rapid destruction of the virus in it, and with a fine abrasive powder, a known aid to successful sap inoculation.

It would, therefore, be most premature to conclude that because successful sap transmission was obtained under these artificial conditions, it *must* follow that nettlehead is spread in the hop garden by the natural wind rubbing of bines and leaves of neighbouring hills or by cultural manipulations such as trimming, stripping, etc. But of course, further work may show that this is indeed happening. Although the application of this discovery to what actually happens in the hop garden, therefore, still has to be found, a most important step forward in research on nettlehead has been made, for we now at least know that nettlehead virus *can* remain active, and therefore be studied, in sap *outside* the hop plant. This opens up much more hopeful prospects for discovering its identity and relationships with other plant viruses, and may thus give good clues to its still undiscovered natural ways and agents of spreading in the hop garden.

The apparently high natural sensitivity of Early Prolific hop to the nettlehead virus was explained

One of the most useful aids to the study of any plant virus is a good ' indicator plant '; that is a plant of another species or variety which can be depended on rapidly to develop symptoms of the virus when infected with it. Some ten years ago, as noted in previous Reports, a selection of the old hop variety Early Prolific from Belgium was found to be just such an indicator of nettlehead, and this has naturally been regarded, hitherto, as an especially useful *natural character* of that variety. An experiment this year, however, has shown otherwise.

Apparently healthy, and certainly nettlehead-free, Early Prolific plants were grafted to healthy Fuggle N and Bramling plants and it was found that these, when then infected with nettlehead virus, developed symptoms much more reliably and rapidly than identical infected plants which had not thus been previously grafted to Early Prolific. The obvious explanation of this result is that our Early Prolific selection was, when it reached us, already infected throughout with a ' latent virus ', that is a virus producing no tell-tale symptoms at all, and that this virus when transmitted to the other and less sensitive varieties Fuggle and Bramling, caused them to become equally good indicators of nettlehead.

How this latent virus of Early Prolific, now referred to as latent virus X, thus increases the sensitivity to nettlehead virus of the hop plant infected with it, has yet to be discovered. It is possible that it may act by speeding up the multiplication of the nettlehead virus directly or indirectly. Whether also this latent virus is present naturally in our hop gardens and may, therefore, be responsible in some measure for the well-known variability in the expression of nettlehead in natural outbreaks, also remains to be investigated. A full description and discussion of this experiment is to be found elsewhere in this Report (p. 106).

The reassessment of the common hop-damson aphid as a possible vector of hop mosaic continues

Resumption of the early work of Paine to test finally whether the hop-damson aphid is, or is not, able to transmit hop mosaic virus was announced last year. This was undertaken on some evidence suggesting that the failure, so far, to repeat the positive results first reported, may have been because only an occasional aphid of the millions normally infesting hops is able to carry and successfully infect plants with the mosaic virus. If this were true then the chance of hitting on such an aphid in transmission experiments would be as remote as discovering the proverbial ' needle in the haystack '. On this assumption much larger numbers of aphids, corresponding to those used by Paine, are being applied in this experiment ; the results are awaited.

Summary

Items of special interest to hop growers in the Station's Report of research in 1960 on Verticillium wilt and the virus diseases of hops are reviewed and discussed.

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Papers already received for publication in the current VOLUME 36 (1961) come from the Sponsor Stations, the Glasshouse Crops Research Institute, the Scottish Horticultural Research Institute, the John Innes Institute, the National Vegetable Research Station, Manchester University and Wye College, and from Canada, New Zealand and Ghana. Fruit crops reported on are apple, plum, raspberry, strawberry and cocoa; there is a first report of investigations on rootstocks for roses; tomatoes, mushrooms and garden beet are the subjects of other papers, while there is also one on the nutrition of a range of vegetable crops. Several physiological studies are described, involving such subjects as flower initiation, influence of environment, storage, and of shade and manuring on cocoa; others describe work on root anatomy, plant breeding, manuring for seed production, frost resistance, fruit tree viruses and the apple spray programme. There is an account of a long term investigation on rootstocks for plums.

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